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ENERGY ANALYSIS

U.S. natural gas prices after the shale boom

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- **Shale production fundamentally altered the relationship between oil and natural gas prices**
- **Although most of the natural gas produced is consumed domestically, exports have also flourished**
- **Henry Hub natural gas prices are likely to increase gradually supported by solid demand**

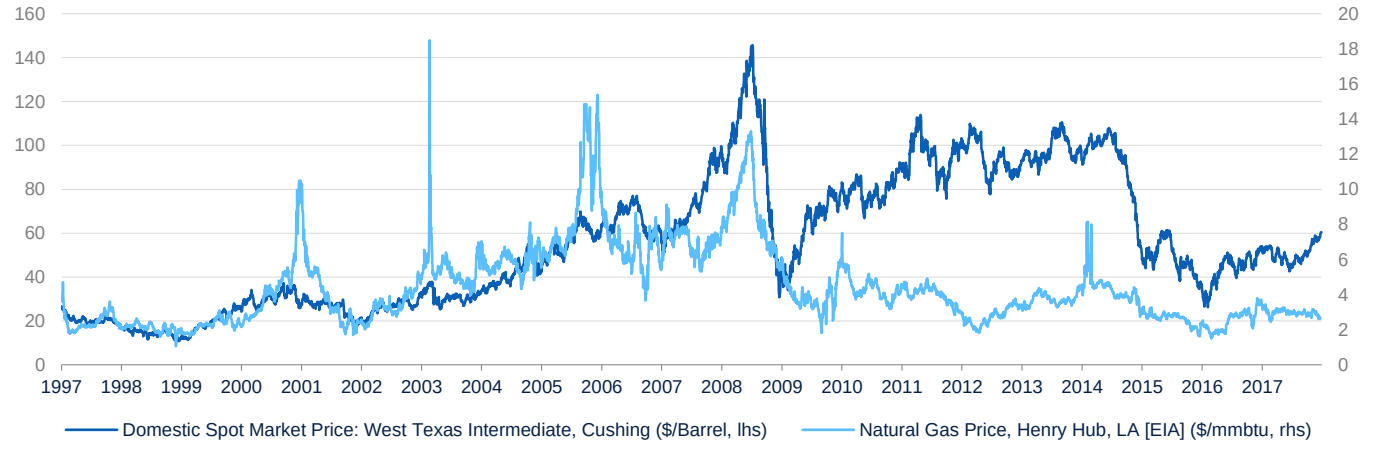
The purpose of this report is to provide a general overview of trends affecting the long-term relationship between natural gas and crude oil prices and to introduce our forecasts for the Henry Hub (HH) natural gas spot price.

The relationship between crude oil and natural gas prices

A visual inspection of the West Texas Intermediate (WTI) crude oil price and the Henry Hub (HH) natural gas price since 1997 (Figure 1) reveals two different phases: One (1997-2008) in which prices move in the same direction, and another (2009-present) in which the comovement weakens significantly with each commodity seemingly following a different path. The strong comovement of prices in the first period has inspired earlier studies that highlight the substitutability between crude oil and natural gas from the demand side (Brown and Yücel, 2008). Moreover, the market dynamics of natural gas were predominately shaped by crude oil due to the size of its global market. Therefore, the stable relationship between the prices of both commodities implied that the path of natural gas prices could be directly predicted as a proportion of crude oil prices (rules of thumbs), or indirectly as a proportion of the price of competing fuels at the consumer's end (burner-tip parity).

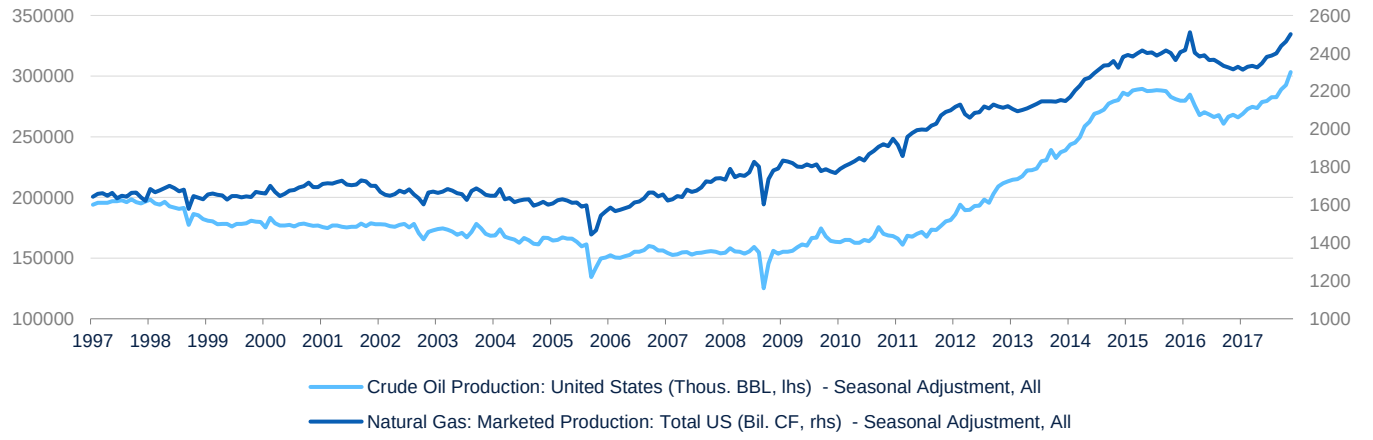
However, the "decoupling" of prices in the second period indicates that supply and demand factors for natural gas have significantly shifted and crude oil's role has become less important in determining natural gas prices (Batten et al., 2017). It is worth mentioning that the breakdown of the relationship coincides with a rapid increase in the production of both commodities resulting from the commercial use of hydraulic fracturing and horizontal drilling (Figure 2), the so-called "shale boom." As the comovement of oil and natural gas prices became weak and unstable, additional variables and more elaborated techniques are needed to produce reliable forecasts for natural gas prices.

Figure 1. U.S. crude oil and natural gas prices



Source: BBVA Research and Haver Analytics

Figure 2. U.S. crude oil and natural gas production

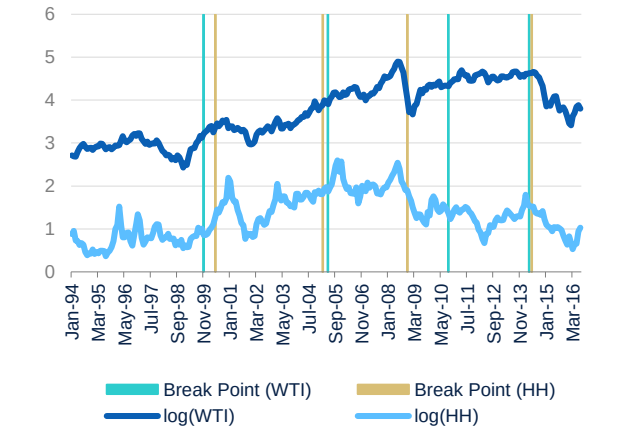


Source: BBVA Research and Haver Analytics

To better understand the decoupling of oil and natural gas prices, we applied the methodology described in Bai & Perron (2003) to detect breaking points (regime changes) in prices of natural gas and crude oil. We also added the production of natural gas to our analysis in order to shed more light on the impact that the "shale boom" had on the dynamics of natural gas prices.

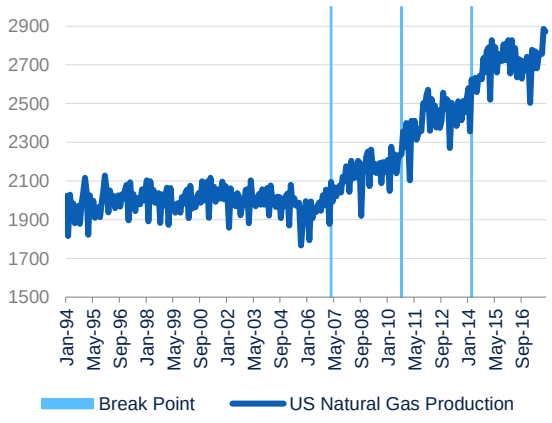
Figure 3, shows that oil and natural gas prices experienced two regime changes before 2008: Both of them relatively close to each other in time. This is consistent with evidence of a long-term relationship between the two variables. However, the statistical analysis shows that the third break point for both natural gas and crude oil prices happened in different years. On the one hand, from June 2008 to September 2009, natural gas prices went from $12.3/mmbtu to $2.69/mmbtu, and quickly recovered around $3.42/mmbtu before slowly declining to lower levels. The estimated break point from the Bai-Perron algorithm is November 2007. On the other hand, since crude oil prices have been extremely volatile in the same period, the same algorithm estimates the break point to be September 2010. The different estimates of break points suggest that the price declines at the end of 2008 had different implications for crude oil and natural gas markets. For crude oil, it was just a period of intense price fluctuation, while for natural gas it was the beginning of a more prolonged downward trend. Finally, we can see that crude oil and natural gas prices shared similar break points in early 2014. As Figure 4 shows, the structural change in prices coincides with a structural change in natural gas production, which is connected to the shale boom.

Figure 3. Crude oil and natural gas prices with structural breakpoints



Source: BBVA Research

Figure 4. Regime change of natural gas production
Billion cubic feet.



Source: BBVA Research

To further test for the presence of a long-term relationship (cointegration) between crude oil and natural gas prices, we estimated a series of vector error correction models (VECM) with two different model specifications for three different sample periods (Table 1). One group of models (Equations (1), (3), and (5)) include two factors that affect the pricing of natural gas: prices of crude oil and domestic production of natural gas. Another group of models (Equations (2), (4), and (6)) represent the mainstream view in studies before 2008, which stress the dominant role of crude oil in determining the price of natural gas.

The results of the regressions for the sample period before 2008 (Equations (3) and (4)) were in line with the findings of previous studies on natural gas prices: 1) the comovement between HH and WTI is almost on a 1-to-1 proportion, and 2) natural gas prices were insensitive to the quantity of natural gas produced. As Brown and Yücel (2008) argued, natural gas can be easily replaced by petroleum products when its price is too high. Therefore at the equilibrium level, the price of natural gas should move along with crude oil prices.

Table 1. Selected coefficients for the cointegration equation of the VECM models

	Regressions with and without natural gas production					
	March 1994 – August 2017		March 1994 – December 2007		January 2008 – November 2017	
	(1)	(2)	(3)	(4)	(5)	(6)
Henry Hub natural gas prices	1	1	1	1	1	1
WTI crude oil prices	-0.80***	-0.51**	-0.99***	-0.99***	-0.46*	-1.17***
Natural gas production	2.96***		-5.6		2.08**	
Constant	-21.08	0.61	44.53	2.02	-15.49	3.75

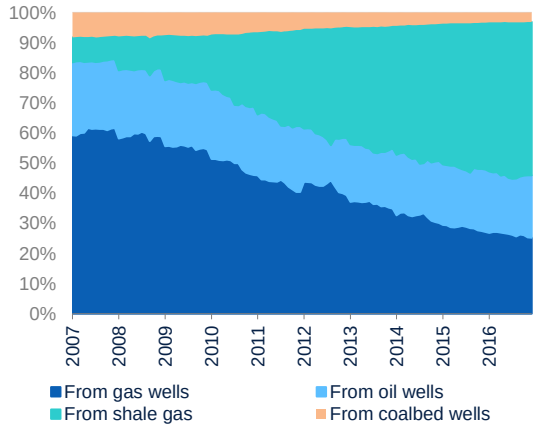
Note: *** p<0.01 ** p<0.05 * p<0.10.
Source: BBVA Research

However, the tight relationship between the two commodity prices weakened after the shale boom. Given the soaring prices of crude oil and sharp increases in natural gas production after 2008, substituting natural gas with petroleum products became increasingly impractical. Therefore, the price of natural gas had to reflect the dynamics of its own market. For the sample period between 2008 and 2017, Equation (6) seems to suggest that the price of crude oil played an even more significant role after the shale boom. However, both the significance and the magnitude of the regression coefficient dropped after we included natural gas production in the model (Equation (5)). That is, in the over-simplified model (6), the increasing price of crude oil after the Great Recession happened to move together with the rising production of natural gas, thus overestimating the impact on natural gas prices. However, once we considered natural gas production, the link between the two commodity prices weakened.

The U.S. natural gas market after 2007

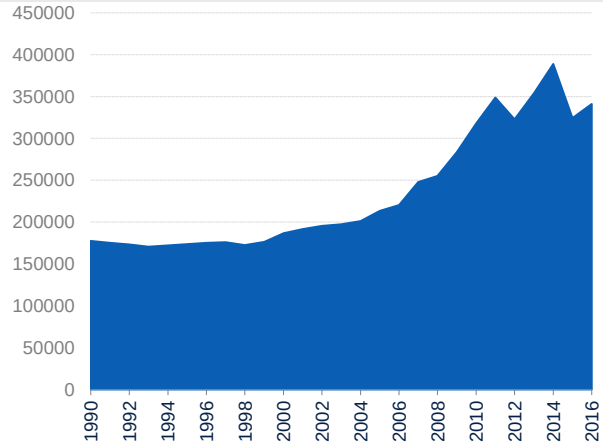
The natural gas industry has experienced a productivity boom due to the introduction of hydraulic fracturing and horizontal drilling that enable access to vast amounts of reserves located in shale formations. Between 2008 and 2016, proved reserves[1] went up by 34% to 341.1 trillion cubic feet (Tcf). From these, 62% (209.8Tcf) are located in shale formations. Between 2008 and 2017, marketed production of natural gas increased 36.5% to 28.8Tcf. Today, about half of U.S. natural gas production comes from shale formations.

Figure 5. U.S. Natural gas gross withdrawals (share of total)



Source: BBVA Research and Haver Analytics

Figure 6. U.S. proved reserves of wet natural gas (Bcf)

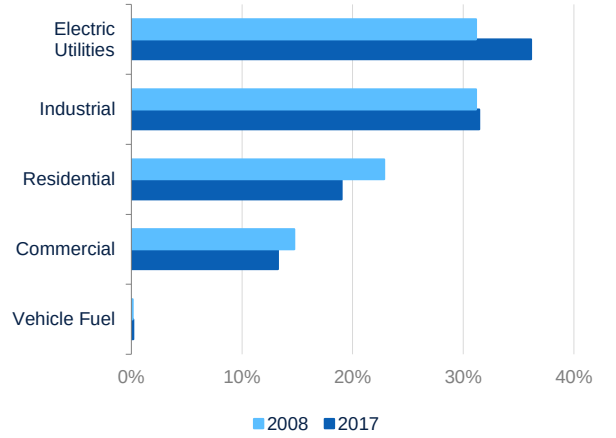


Source: BBVA Research and Haver Analytics

The abundance created by the "shale boom" and the consequent decline in prices encouraged more consumption of natural gas, which increased by 28% in the aforementioned period. By sector, consumption of natural gas increased the most in the electric utility sector (62%), driven by lower prices and more stringent environmental regulations that incentivized a switch from coal- to natural gas-fired plants. As a result, the share of natural gas in electricity generation went from 30% to 36%. Natural gas is expected to become the most important fuel in the United States, supplying 40% of the country's total energy needs by 2040[2].

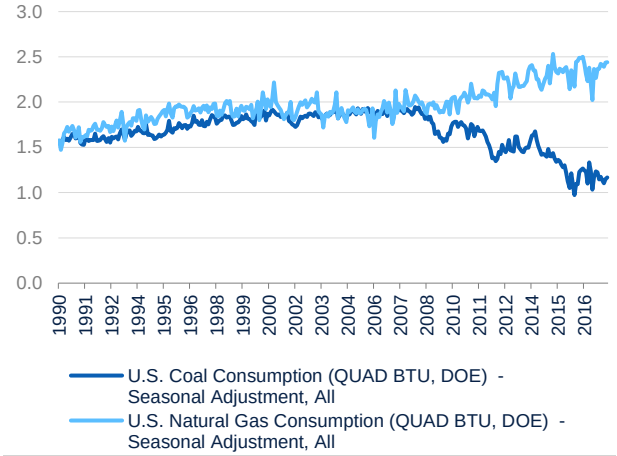
1: "The proved reserves of natural gas as of December 31 of any given year are the estimated quantities of natural gas which geological and engineering data demonstrates with reasonable certainty to be recoverable in the future from known natural oil and gas reservoirs under existing economic and operating conditions." Source: EIA
2: BP Energy Outlook, https://www.bp.com/en/global/corporate/energy-economics/energy-outlook/

Figure 7. U.S. natural gas consumption by sector, share of total



Source: BBVA Research and Haver Analytics

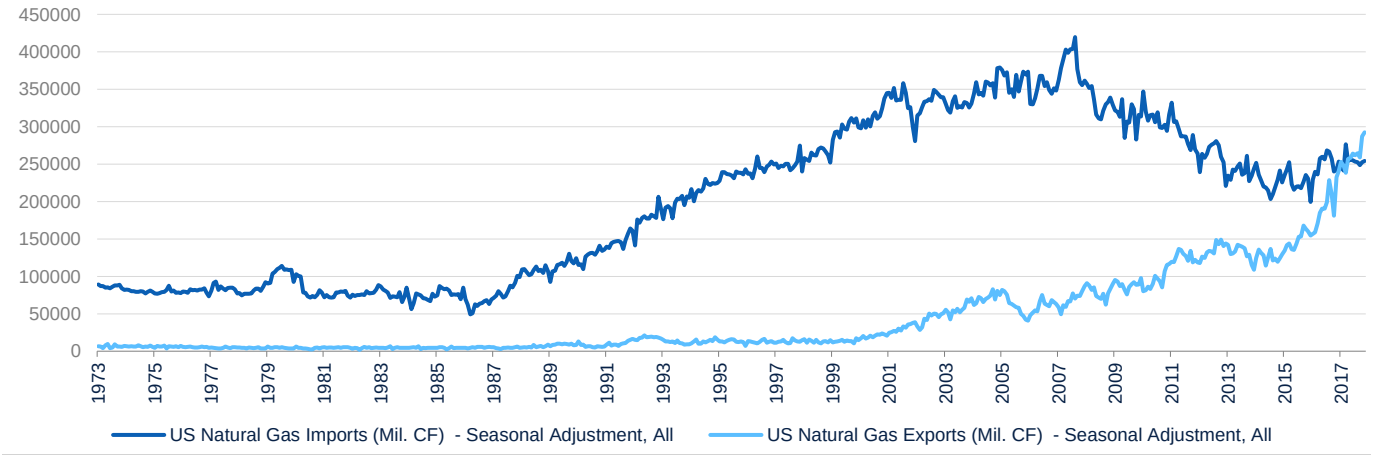
Figure 8. U.S. energy consumption by source



Source: BBVA Research and Haver Analytics

The production boom triggered an import substitution process. Although most of the natural gas produced in the U.S. is consumed domestically, exports have also flourished to the point that the country may consolidate as a net exporter sometime in 2018. The two major destinations for natural gas exports are Mexico and Canada (via pipelines); however, exports are expected to reach many more countries as new technologies and transportation capacity allow the maritime shipment of liquified natural gas (see U.S. natural gas exports: a reliable supply of energy to the rest of the world).

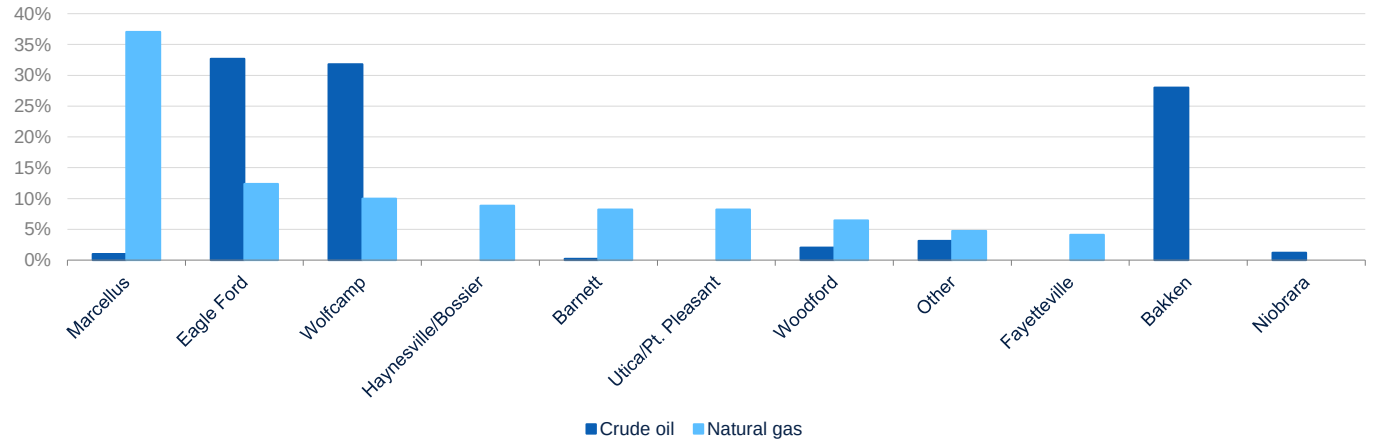
Figure 9. U.S. imports and exports of natural gas



Source: BBVA Research and Haver Analytics

Furthermore, the “shale boom” has changed the geographical distribution of natural gas production relative to that of crude oil. The Marcellus shale play concentrates 40% of shale gas production, but only 1% of tight oil production. Conversely, the Bakken shale play accounts for 28% of tight oil production, but virtually none of the shale gas production. The Eagle Ford and the Wolfcamp shale plays have a relatively more balanced distribution of oil and natural gas output. However, their share of total tight crude oil production is three times bigger than that of shale natural gas. This geographical disparity creates a natural hedge against adverse shocks to crude oil production, helping natural gas prices to remain stable.

Figure 10. U.S. crude oil and natural gas production by shale play (share of total)



Source: BBVA Research and Energy Information Administration

Natural gas prices projections (2018-2022)

Based on the analysis described above, we have produced forecasts for Henry Hub prices using a series of supply and demand variables such as industrial production, number of heating and cooling days, imports, exports and natural gas production. All variables are adjusted for seasonality. As Table 2 shows, all the statistically significant coefficients have the right sign. As expected, one of the largest elasticities comes from the production of natural gas, which is consistent with the structural change brought by the “shale boom.” The incorporation of industrial production and WTI to the model allows us to link the outlook for natural gas prices to our macroeconomic scenario. For the sake of simplicity, we assume that heating and cooling days move according to its long-term trend, but they can be manipulated to reflect structural changes in weather patterns. Two alternative scenarios were created to reflect upside and downside assumptions on industrial production and oil prices (see Oil Prices Outlook 2018-2022). Forecasts for natural gas production are taken from the Energy Information Administration’s Annual Energy Outlook 2018.

Table 2. Coefficients for the natural gas prices forecasting equation

HH Natural gas prices	Coef.
Oil prices (WTI)	0.25***
Natural gas production	-3.09***
Heating degree days	1.12***
Cooling degree days	-0.03*
Exports of natural gas	0.16***
Imports of natural gas	0.15
Industrial production	3.7***
Constant	-2.41

Note: *** p<0.01 ** p<0.05 * p<0.10.

Source: BBVA Research

Table 3. Henry Hub natural gas price projections ($/mmbtu)

	Baseline	Upside Risk	Downside Risk
2017	2.96	2.96	2.96
2018	**3.04**	**3.30**	**2.78**
2019	**3.08**	**3.45**	**2.29**
2020	**3.10**	**3.52**	**2.02**
2021	**3.15**	**3.82**	**1.98**
2022	**3.21**	**4.16**	**1.99**

Source: BBVA Research

According to our model, Henry Hub prices are expected to increase gradually supported by demand, particularly in the electricity and industrial sectors. On the domestic side, the U.S. economy is expected to continue growing at a solid pace supported by fiscal reform. The transition from coal to natural gas in electricity production is assumed to continue through the forecast period. The world's demand for U.S. natural gas is expected to expand further supported by growing electricity demand in Mexico and increasing appetite for U.S. liquefied natural gas in Europe and Asia. The upside coming from demand will be partially compensated by growing domestic production and relatively low crude oil prices, which according to our scenario, will stabilize around $60/b.

Bottom line

The cointegration relationship between WTI oil prices and HH natural gas prices was altered by the production boom triggered by the commercial use of hydraulic fracturing and horizontal drilling. Low prices have encouraged more consumption of natural gas, particularly in the electricity and industrial sectors. Higher production has also resulted in more exports, which are likely to increase further and reach more markets. Although we expect HH prices to increase between 2018 and 2022, they will remain low enough to continue supporting economic growth and strengthening energy security.

Going forward, as international demand for U.S. natural gas increases, the Henry Hub benchmark will be more affected by global outcomes, potentially restoring its cointegration relationship with the WTI. In addition, natural gas prices could experience more structural breaks resulting from climate change (e.g. a potential reduction in the average number of heating days), the electrification of transportation, improvements in energy efficiency, and the rapid decline in the cost of renewables.

References

Bai, J., & Perron, P. (2003). Computation and analysis of multiple structural change models. Journal of Applied Econometrics, 18(1), 1-22.

Batten, J. A., Ciner, C., & Lucey, B. M. (2017). The dynamic linkages between crude oil and natural gas markets. Energy Economics, 62, 155-170.

Brown, S. P., & Yücel, M. K. (2008). What drives natural gas prices? The Energy Journal, 45-60.