***The switching relationship between natural gas and oil prices***

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## Overview

We more accurately capture the cointegrating relationship between natural gas and crude oil by controlling for nonstationarity induced by endogenous changes in regime. Specifically, we allow the cointegrating equation to switch between *m* states, according to a first-order Markov process. First, we find evidence that regime-switching exists in the relative pricing relationship, and that two is the optimal number of states. Once we control for this type of nonstationarity natural gas and crude oil prices are cointegrated, and in an error correction model the state weighted residuals contain unique information and allow for faster recovery toward equilibrium in response to exogenous shocks. This allows better measures of present energy market integration, possibly better forecasts of relative prices, and a more thorough understanding of how technological changes affect the natural gas and crude oil pricing relationship.

Further, our analysis finds evidence that natural gas and crude oil prices did not permanently ‘decouple’ in the early 2000s, but rather experienced a temporary shift in regimes. We conclude that the relative pricing relationship of natural gas and crude oil should be conditioned on state probability.

## Methods

We estimate a natural gas and crude oil cointegrating equation with first-order, M-state, endogenous Markov-switching parameters. To determine the appropriate number of states, the cointegrating equation was estimated allowing for the number of states to range from one to three. Note, a one-state equation is the standard, non-switching, cointegrating equation. The results of each model were compared using Akaike’s Information Criterion (AIC).

The residuals of the *m*-state model are weighted by *filtered* state probability, which is the probability that the relationship is in state *St* given information only through time *t-1*. We then tested for stationary residuals in the cointegrating equation using both the Augmented Dickey-Fuller and the Phillips-Perron tests.

Lastly, we use the state-weighted residuals from the switching cointegration regression to estimate an error-correction model (ECM) of natural gas and crude oil prices. We then compare these results to the same ECM estimated using a standard non-switching cointegrating term.

## Results

We find evidence for a regime-switching relationship between natural gas and oil prices. This evidence is, firstly, that the cointegrating equation is well-suited to a regimeswitching model with two states. The cointegrating equation’s residuals are stationary when using the switching model, and nonstationary when the relationship is constrained to one state. The filtered probabilities also exhibit stable states with distinct regime-switching.

Additional evidence for the superiority of the regime-switching model is found by comparing the results of an ECM of natural gas and crude oil prices with two-state residuals, to the results of the same ECM using one-state residuals. We found that the ECM with two-state residuals recovers from an exogenous shock at over twice the rate of the ECM with one-state residuals. Further, we found that in the ECM, the two-state cointegrating term contains uniqueinformation whereas the one-state term contains redundant information.

## Conclusions

Firstly, this analysis shows there is a stronger relationship between natural gas and crude oil once one controls for switches in regimes. That is, when controlling for endogenous regime switching there is faster reversion of natural gas and crude oil prices to their long-term equilibrium, which implies these energy markets are more integrated that one would otherwise estimate.

The results also imply that natural gas and crude oil prices did not permanently decouple in the early 2000s, but rather exhibited a temporary shift in August of 2000 to a regime wherein natural gas prices performed relatively better than crude oil prices. This regime lasted, with one interruption, until approximately May of 2009, after which the relationship has reverted to itsoriginal state with oil price increases outpacing natural gas prices.

The evidence in this analysis shows that there is unique information gained through allowing endogenous regime switching when considering the long-term relative prices of natural gas and crude oil. This information allows a more thorough and accurate understanding of the relationship. In sum, the relative pricing relationship of natural gas and crude oil should be conditioned on state probability.

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