The Relationship between Natural Gas Prices and the Rig Count

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Introduction

This paper investigates the existence and extent of state dependence in the relationship between natural gas and the rig count, and the implications of such state dependence for explaining changes in these series.

- In particular, this analysis finds evidence that the rig count can be an important determinant of the changes in natural gas prices

Introduction

Prior literature on explaining the changes in natural gas prices has included the gas rig count only incidentally through an exogenous 'shutin' variable, which measures the proportion of natural gas production idled (mainly due to hurricanes in the Gulf of Mexico).

- In this analysis, we first show that if you do not consider state dependence in the relationship between natural gas and the rig count, then you would come to the conclusion that natural gas affects the rig count, however the rig count does not affect natural gas prices.
  - Thus the rig count would not need to be included as an explanatory variable for changes in natural gas prices.
- However, once you consider state dependence (where the state is dependent on the lagged natural gas price) then the rig count significantly affects natural gas.

Introduction

In related research, Boudoukh et al (2007) illustrated the importance of including state dependence in the structural relationship between an asset's returns and its fundamentals. They do so by showing temperature affects frozen concentrate orange juice futures returns only when the temperature is near freezing.

- If the state dependence is not accounted for, then it appears temperature has no effect on orange juice futures returns.

Motivation for State Dependence

We expect state dependence between natural gas and the rig count to be driven by natural gas prices falling below marginal production costs.

- when natural gas prices are near or below production costs, then the rig count will be highly dependent on natural gas prices (more costly rigs are idled). $NG \Rightarrow RC$
- when natural gas prices are well above their production costs, increases in the rig count will cause a reduction in natural gas prices (as all rigs are brought online). $RC \Rightarrow NG$

A recent article[1] in the financial press highlights the relationship between natural gas prices and the rig count. From the article:

> *Gas producers in North America including Chesapeake Energy Corp. (CHK) are killing their commodity's biggest rally in 10 months by opening more wells, putting the U.S. on track to have record gas supplies this year.*

[1] http://www.bloomberg.com/news/2012-11-14/gas-prices-doomed-to-stay-low-as-producers-pump-faster.html

Data

- Monthly price data are from the EIA.
  - Natural gas (Henry Hub)
  - Crude oil (west Texas intermediate - Cushing OK)
  - Heating oil (NY harbor)
    - all price data are logged and differenced
- The North American gas rotary rig count is from Baker Hughes.
- $STOR$ denotes the monthly deviation of the total working gas in storage from its 5-year average for that month
- CDD and HDD are population-weighted national averages and are available from the U.S. National Weather Service's Climate Prediction Center.
- $HDDdev$ and $CDDdev$ denote the deviation of monthly total HDD and CDD from their historical monthly norm.

Threshold $VAR(p)$

Let $\mathbf{r}_t = (\Delta ng_t,\ \Delta rc_t)'$ where $\Delta ng_t = ng_t - ng_{t-1}$ and $\Delta rc_t = rc_t - rc_{t-1}$. Then we have the multivariate threshold VAR:

$$\mathbf{r}_t = \begin{cases} \mathbf{c}_1 + \sum_{i=1}^{p} \mathbf{\Phi}^{(1)}{}_i \mathbf{r}_{t-1} + \sum_{i=1}^{p} \mathbf{\Lambda}_i^{(1)} \mathbf{Z}_{t-1} + \mathbf{a}_t^{(1)} & \text{if } ng_{t-1} \leq \gamma \\ \mathbf{c}_2 + \sum_{i=1}^{p} \mathbf{\Phi}^{(2)}{}_i \mathbf{r}_{t-1} + \sum_{i=1}^{p} \mathbf{\Lambda}_i^{(2)} \mathbf{Z}_{t-1} + \mathbf{a}_t^{(2)} & \text{if } ng_{t-1} > \gamma \end{cases} \tag{1}$$

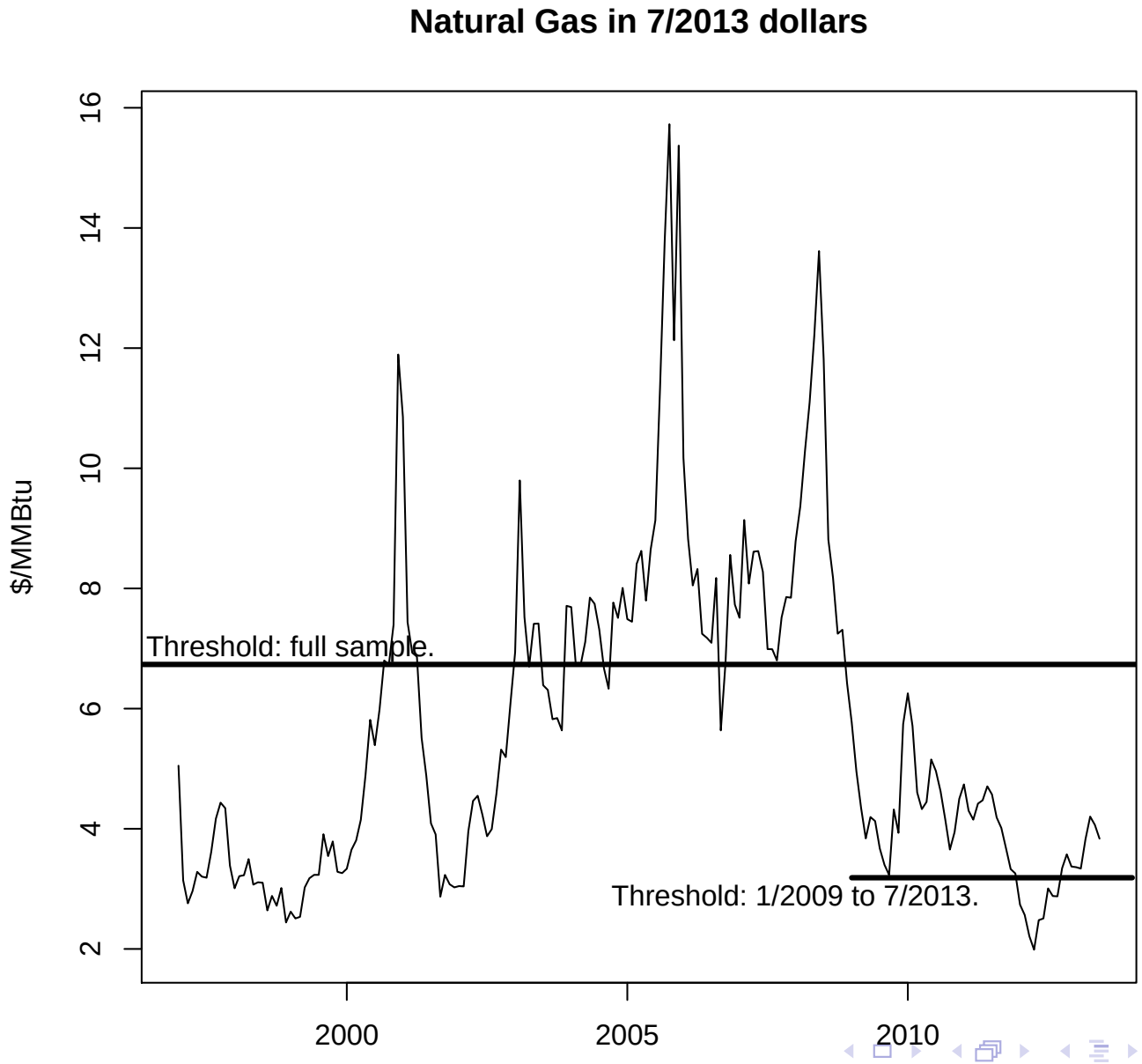
where ng_{t-1} is the threshold variable, and γ is the estimated threshold. $\mathbf{Z_{t-1}}$ is an optional vector of exogenous variables.

Results: No State Dependence

- Natural gas Granger-causes the rig count at the 0.1% level of significance.
- The rig count does not Granger-cause natural gas prices.

This result explains why earlier analyses of the determinants of the changes in natural gas prices have not included the rig count as an explanatory variable.

Results: With State Dependence



Results: With State Dependence

Table: Threshold VAR Results on the full sample from February 1997 to June 2013. The sample size is 197 and there are 21 estimated parameters. NG denotes natural gas in \$/MMBtu in July 2013 dollars, and ng denotes its natural log. rc denotes the natual log of the north American natural gas rig count. The standard error is below each estimated coefficient in parentheses. . **, ***, *** denoted statistical significance at the 10%, 5%, 1%, and 0.1% level respectively.

Estimated Threshold: Natural Gas is \$6.74/MMBtu				
	$NG_{t-1} <$ \$6.74		$NG_{t-1} >$ \$6.74	
	Δng_t	Δrc_t	Δng_t	Δrc_t
constant	0.0132	-0.0013	-0.0081	0.0035
	(0.0117)	(0.0029)	(0.0197)	(0.0049)
Δng_{t-1}	0.0620	0.0716	0.0799	-0.0002
	(0.0979)	(0.0241)**	(0.1033)	(0.0254)
Δrc_{t-1}	0.0850	0.6481	-2.8135	0.3478
	(0.3139)	(0.0773)***	(0.7730)***	(0.1904).
Δng_{t-2}	0.0975	0.0703	-0.1040	0.0314
	(0.0961)	(0.0237)**	(0.0989)	(0.0244)
Δrc_{t-2}	0.0108	0.0327	2.0608	0.2062
	(0.3105)	(0.0765)	(0.8028)*	(0.1977)
AIC	-2117.407			

Tests for Granger-causation

Table: Tests for Granger-causality in the full-sample Threshold $VAR(2)$. $\Rightarrow$ denotes Granger-causation. ng denotes natural log of natural gas prices. rc denotes the natural log of the north American natural gas rig count. The p-value is below each estimated coefficient in parentheses. . **, ***, *** denoted statistical significance at the 10%, 5%, 1%, and 0.1% level respectively.

Estimated Threshold: Natural Gas is \$6.74/MMBtu		
	$NG <$ \$6.74	$NG >$ \$6.74
	F-Statistic	F-Statistic
$\Delta ng \Rightarrow \Delta rc$	13.4962	1.6963
	(0.0000)****	(0.1920)
$\Delta rc \Rightarrow \Delta ng$	0.2577	4.1683
	(0.7731)	(0.0201)**

Results: With State Dependence

The threshold was estimated to be \$6.74/MMBtu (in July 2013 dollars).

Below the threshold:

- Both lagged changes in natural gas and the rig count positively and significantly affect present changes in the rig count.
- Natural gas is unaffected by lagged changes in natural gas and the rig count.

Above the threshold:

- Lagged changes in the rig count have a negative and significant affect natural gas.
- Natural gas does not affect the rig count.

Results: With State Dependence

- This is evidence that both the sign of the natural gas and rig count relationship, and the flow of causation, are state-dependent.
- The results are consistent with the anecdotal evidence that, in response to rallies in natural gas prices, producers increase the rig count to such as extent that natural gas prices are depressed.
- The results motivate the inclusion of the rig count, as a state-dependent variable, in analyses of natural gas price changes at the monthly sampling frequency and longer.

Results: Subsample

During the 2008 financial crisis the (inflation adjusted) price of natural gas fell below \$6/MMBtu, and has stayed below this value since. We have estimated the threshold VAR over the period January 2009 to July 2013.

- We find a lower threshold of \$3.19/MMBtu.
- Tests for Granger-causation are insignificant (likely too few data).

Results: With Exogenous Variables

- We test whether our earlier results are robust to the inclusion of exogenous variables, which are commonly known to affect natural gas prices, in the VAR.
- The exogenous variables are the deviation of US working gas in storage from its 5-year average ($STOR$), the deviation of CDD and HDD from their long term norm ($CDDDev$ and $HDDDev$ respectively), and lagged changes in logged crude oil prices (west Texas intermediate).

Results: With Exogenous Variables

- Consistent with our main result, above the threshold lagged chages in the rig count negatively and significantly affect natural gas price changes. Also consistent is that natural gas does not significantly affect the rig count above the threshold.
- The main difference from the earlier $VAR(2)$ without exogenous variables, is that the natural gas price threshold is \$8.05/MMBtu, as opposed to \$6.74. Note, the maximum natural gas price over the period was \$15.72/MMBtu.

Table: Threshold VAR Results on the full sample from February 1997 to June 2013 with the inclusion of exogenous variables. The sample size is 192 and there are 53 estimated parameters.

Estimated Threshold: Natural Gas is \$8.05/MMBtu				
	$NG_{t-1} <$ \$8.05		$NG_{t-1} >$ \$8.05	
	Δng_t	Δrc_t	Δng_t	Δrc_t
constant	0.0015	0.0025	-0.0152	0.0122
	(0.0128)	(0.0034)	(0.0407)	(0.0109)
Δng_{t-1}	-0.0122	0.0764	-0.3730	-0.0235
	(0.0886)	(0.0238)**	(0.2826)	(0.0760)
Δrc_{t-1}	-0.0423	0.5782	-5.7693	0.2356
	(0.2800)	(0.0753)***	(1.3409)***	(0.3609)
Δwti_{t-1}	-0.0611	0.0047	-0.1215	0.0845
	(0.1170)	(0.0315)	(0.3711)	(0.0999)
$STOR_{t-1}$	-0.0006	7.9e-05	2.0e-05	-3.0e-05
	(0.0001)***	(3.9e-05)*	(0.0005)	(0.0001)
$CDDdev_{t-1}$	-0.0007	0.0001	0.0043	-9.8e-05
	(0.0006)	(0.0001)	(0.0016)**	(0.0004)
$HDDdev_{t-1}$	-0.0006	8.8e-05	0.0016	-8.6e-05
	(0.0003)*	(7.4e-05)	(0.0007)*	(0.0002)
Δng_{t-2}	-0.0136	0.0553	0.4601	0.0221
	(0.0834)	(0.0224)*	(0.2474).	(0.0666)
Δrc_{t-2}	0.1535	0.0718	2.2238	-0.5860
	(0.2773)	(0.0746)	(1.9297)	(0.5193)
Δwti_{t-2}	0.2201	0.1224	0.9746	0.0402
	(0.1183).	(0.0318)***	(0.3190)**	(0.0858)
$STOR_{t-2}$	0.0006	-9.1e-05	0.0001	1.7e-05
	(0.0001)***	(3.6e-05)*	(0.0005)	(0.0001)
$CDDdev_{t-2}$	-2.2e-05	-0.0001	-0.0046	-1.2e-05
	(0.0005)	(0.0001)	(0.0015)**	(0.0004)
$HDDdev_{t-2}$	-0.0003	-1.4e-05	-0.0010	6.4e-05
	(0.0002)	(6.4e-05)	(0.0006).	(0.0002)
AIC	1136.5710			

Conclusion

The rig count is an important determinant of the changes in natural gas prices.

- Taking into account state dependence, as natural gas increases above a price threshold, changes in the rig count negatively and significantly affect (Granger-cause) subsequent changes in natural gas prices.
  - This means natural gas prices decline in response to an increase in the rig count.
- Below the price threshold, changes in natural gas prices positively and significantly (Granger-cause) subsequent changes in natural gas prices.

Conclusion

This evidence is consistent with media reports stating natural gas producers often 'kill the commodity's rally'.

- That is, as natural gas prices rise while below the threshold, rigs with increasing marginal production costs are brought online in response.
  - Gas prices affect the rig count.
- When prices rise above the threshold, and a large proportion of rigs are potentially profitable, enough supply is provided to negatively affect gas prices.
  - The rig count affects gas prices.

Conclusion

- These results have practical implications for understanding changes in gas prices, and for implementing future models thereof.
- These results are likely of interest to natural gas producers, who have much to lose if they are the last to bring a rig online in the face of declining gas prices.
  - This analysis may help producers identify the price threshold above which the rig count will negatively affect gas prices, and thereby choose to not increase the rig count above this price.