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DO ARBITRAGE OPPORTUNITIES EXIST IN THE NATURAL GAS MARKET?

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ABSTRACT

This paper investigates the relationship between natural gas spot and futures prices by using threshold error correction model developed by Hansen and Seo (2002) and threshold granger causality test developed by Li (2006). We found that there is a threshold cointegration relationship between spot and futures prices of natural gas. We also found that there is partially bidirectional causality between spot and futures prices of natural gas. The evidence obtained from this paper also suggests that there is information flow between natural gas spot and future market and there is no profitable arbitrage opportunity exists.

Keywords: Natural gas spot and futures prices, threshold error correction, threshold granger causality

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1. Introduction

The three functions which a futures market is expected to provide are price discovery, transfer of risk, and transaction cost reduction (Lien and Root 1999). Prices in futures and forward markets can also provide signals for investments in the power system infrastructure, and thereby contribute to an adequate development of supply and demand. These markets also represent an opportunity for trading and speculation, both for power companies and financial market players (Botterud et. al. 2010).

There are several theoretical models in the literature that explain why we should expect a relationship between spot and futures prices. The precise nature of this relationship will depend on the nature of the commodity, its relative importance in the World economy, seasonal factors, market expectations and the random realization of the news (Maslyuk and Smyth 2009).

The theoretical connection between spot and futures prices is a long-run, rather than short run, concept. In the short-run, there might be deviations between spot prices and derivative prices. These deviations can be induced by thin trading, lags in information transmission, insufficient inventory levels and seasonal patterns of consumption (Maslyuk and Smyth 2009).

Within United States economy, natural gas plays a major role because it accounts for almost a quarter of the total annual energy. It is expected that US natural gas consumption will continue to increase due to relatively competitive market structure, and environmental standards that encourage increased use or combustion of cleaner fuels for the generation of electricity (Gebre-Mariam 2011).

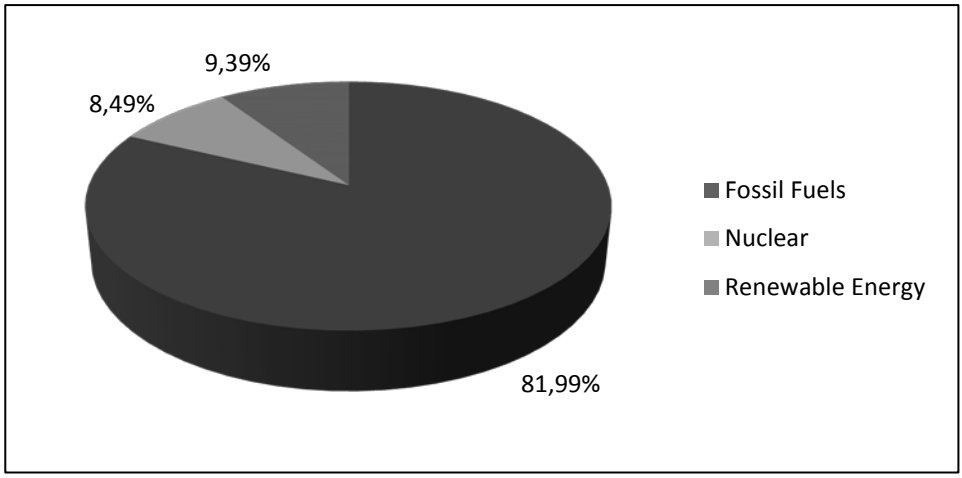


Figure 1: US Primary Energy Consumption by Source

Figure 1 represents the US primary energy consumption by source in 2011. As can be seen from the figure, the percentages of primary energy consumption from the fossil fuels, nuclear energy and renewable energy are 81.99%, 8.49%, 9.39%, respectively.

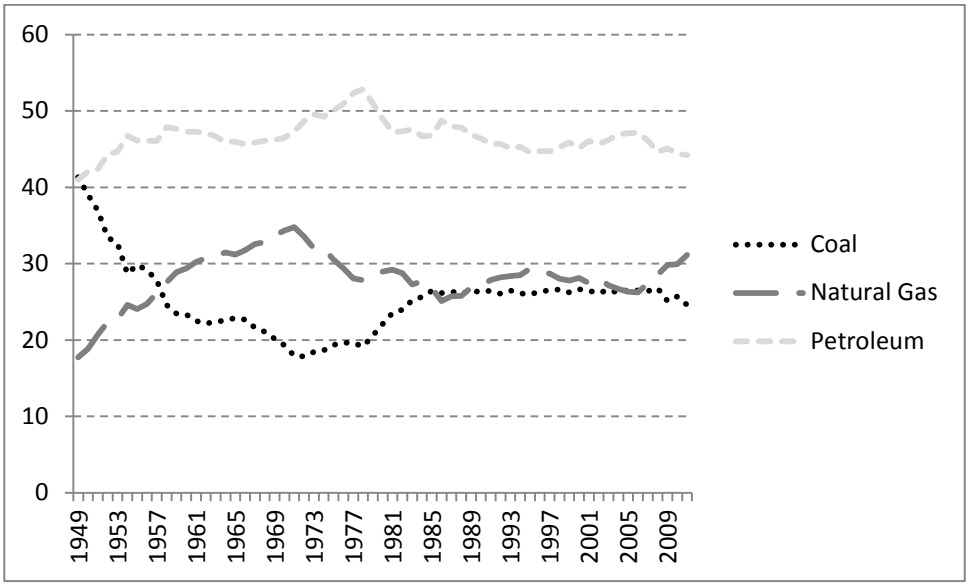


Figure 2: US Fossil Fuels Energy Consumption by Source

The percentage of US fossil Fuels energy consumption by source has been presented in Figure 2. Over the period 1949 – 2011, percentage of petroleum consumption climbed from 40% to 44%, while percentage of coal consumption ascended from 41% to 24%. In the same period the percentage of natural gas consumption climbed from 17% to 31%.

Natural gas is at the heart of the debate about the present and future of energy in the US. According to Golpe et.al (2012), there are several reasons behind this growing interest in natural gas. Firstly, natural gas is considered as a promising candidate for meeting future demand under carbon dioxide (CO2) emissions constraints. Secondly, the US has new disposals of low cost gas that provide an enormous potential benefit to the nation remember that the US has particularly large reserves of shale gas. Finally, the US natural gas industry has been subject to several regulatory reforms with the aim of converting the natural gas market into a more competitive and efficient one.

In recent years, several studies mainly examine the causal relationships between spot and futures commodity prices. [Silvapulle and Moosa (1999), Benz and Trück (2009), Milunovich and Joyeux (2007), Chevalier (2010), Uhrig-Homburg and Wagner (2009), Arouri et. al. (2012)]. The purpose of this paper is to fill the gap in

the empirical literature on the casual relationship between spot and futures prices of natural gas by using nonlinear techniques. To our knowledge, no attempts have so far been made to investigate the relationship between spot and futures prices of natural gas by using threshold models.

The rest of the paper is organized as follows: Section 2 deals with the econometric methodology, Section 3 describes data and empirical results and Section 4 gives the summary and conclusions.

2. Methodology

In order to investigate the relationship between spot and futures prices of natural gas, this study applied a threshold error correction model. Unlike the standard error correction model which assumes linearity and symmetric adjustment in every time period, threshold cointegration models, introduced by Balke and Fomby (1997), combine nonlinearity and cointegration. This model allows discontinuous adjustment to equilibrium when the system exceeds a certain threshold, for the cost of adjustment are lower than the benefits, and economic agents move the system back to equilibrium. A threshold VECM described as follows:

$$\Delta x_t = \begin{cases} A_1' X_{t-1}(\beta) + u_t & if \quad w_{t-1}(\beta) \le \gamma \\ A_2' X_{t-1}(\beta) + u_t & if \quad w_{t-1}(\beta) > \gamma \end{cases} \tag{1}$$

where,

$$X_{t-1}(\beta) = \begin{pmatrix} 1 \\ w_{t-1}(\beta) \\ \Delta x_{t-1} \\ \Delta x_{t-2} \\ \vdots \\ \vdots \\ \Delta x_{t-l} \end{pmatrix} \tag{2}$$

γ is a threshold parameter, x_t is a p-dimensional $I(1)$ time series which is co-integrated with one $p\ x\ 1$ co-integrating vector β, $w_t(\beta) = \beta' x_t$ is the $I(0)$ error correction term A_1 and A_2 are coefficient matrices, u_t is an error term.
The threshold error correction model can alternatively be written as,

$$\Delta x_t = A_1' X_{t-1}(\beta) d_{1t}(\beta, \gamma) + A_2' X_{t-1}(\beta) d_{2t}(\beta, \gamma) + u_t \tag{3}$$

where

$$d_{1t}(\beta, \gamma) = 1(w_{t-1}(\beta) \le \gamma)$$
$$d_{2t}(\beta, \gamma) = 1(w_{t-1}(\beta) > \gamma) \tag{4}$$

Here, $1(.)$ denotes the indicator function.

Hansen and Seo (2002) made two contributions. First, they proposed a method to implement maximum likelihood estimation of the threshold model. Second, they developed a test for the presence of a threshold effect. Under the null hypothesis, there is no threshold so the model reduces to a conventional linear VECM. This test statistic can be denoted as,

$\sup LM = \sup_{\gamma L \le \gamma \le \gamma U} LM(\tilde{\beta}, \gamma)$

where $\tilde{\beta}$ is the estimate of β. $[\gamma_L, \gamma_U]$ is the search region set so that γ_L is the π_0 percentile of $\widetilde{w}_{t-1}$, and γ_U is the $(1-\pi_0)$ percentile. Andrews (1993) suggests setting π_0 between 0.05 and 0.15. To calculate the asymptotic critical values and p-values of the sup LM test, Hansen and Seo (2002) developed two bootstrap methods. Threshold model and granger causality analysis have been combined by Li (2006). Two regime threshold autoregressive distributed lag TADL (p,q,τ,d) model can be shown

$$y_t = \sum_{m=1}^{2}\left(a_m + \sum_{i=1}^{p} b_{mi} y_{t-i} I_{mt} + \sum_{j=1}^{q} c'_{mj} x_{t-j} I_{mt}\right) + e_t \qquad (5)$$

where $I_{1t} = I(y_{t-d} > \tau)$ and $I_{2t} = 1 - I_{1t}$, $x_t = (x_{1t}, \ldots., x_{kt})'$ is a kx1 vector at time t. Li(2006) considers three null hypotheses given by

$H_0^0 = c_{11} = c_{21} \ldots.. = c_{1q} = c_{2q}$
$H_0^1 = c_{11} = \cdots = c_{1q}$
$H_0^2 = c_{21} \ldots.. = c_{2q}$

where H_0^0 implies that none of the covariates has predictive content in the two regimes, H_0^i implies no predictive content in regime i, i=1,2.

According to Li (2006), all hypotheses are tested based on the Wald statistic, written as

$$W = \left(R\hat{\theta}\right)'\left[R\left(\sum z_t z_t'\right)^{-1}\left(\sum \hat{e}_t^2 z_t z_t'\right)\left(\sum z_t z_t'\right)^{-1} R'\right]^{-1}\left(R\hat{\theta}\right) \qquad (6)$$

where R is the selection matrix for the null hypotheses, θ are parameters estimates,
$z_t = \partial f(\theta)/\partial\theta$, $f = E(y_t/\Omega_{t-1})$ and $\hat{e}_t$ is the OLS or NLS residuals. Li (2006) also showed that $W \sim \mathcal{X}^2(m)$, where m is the number of restrictions and standard asymptotic results are applicable.

3. Data and Empirical Results

In order to investigate the relationship between spot and futures prices of natural gas, we use monthly data over the period 2000:1 - 2012:11. All data have been collected from the US Energy Information Administration and were converted into natural logarithmic form before the empirical analysis.

As a first step of the analysis, we have tested for the order of integration of these variables. To do this we use ADF, PP, KPSS and NG – Perron tests. Results of these tests are reported in Table 1.

Table I: Unit Root Test Results

	ADF	PP	KPSS
LNSPOT	-2.467868	-2.751139	0.306434
LNFUT	-2.687302	-2.668974	0.316097
ΔLNSPOT	-11.49303*	-11.52045*	0.029886*
ΔLNFUT	-10.30479*	-10.23691*	0.032088*
	Ng – Perron		
	MZa	MZt	MSB	MPT
LNSPOT	-5.63962	-1.61876	0.28703	16.0341
LNFUT	-7.44544	-1.87743	0.25216	12.3543
ΔLNSPOT	-75.6454*	-6.14651*	0.08115*	1.23551*
ΔLNFUT	-73.3326*	-6.04850*	0.08248*	1.27206*

* indicates rejection of unit root null hypothesis at 1% significance level.

Spot and futures prices of natural gas cannot reject the null hypothesis of unit root in the level. All the variables in first differences are stationary, because the first difference rejects the null hypothesis at the 1% significance level. Given that the integration of the series is of the same order, we continued to test whether these two series are co-integrated over the sample period. The next step of empirical analysis is to test the presence of a threshold effect.

Because the selection of lag lengths is an important stage of threshold methodology, before testing threshold effect, it can be estimated with the help of information criteria. The order of lag selected by Akaike Information Criterion (AIC) is estimated as 1. Using this finding, sup LM test proposed by Hansen and Seo (2002) is used to test the presence of threshold effect. Table 2 presents the Sup LM test results.

Table II: Sup LM Test Result

	SPOT - FUTURES		
Test Statistic	18.0489	p value	0.0488
Critical Values	0.90%	16.59678	
	0.95%	18.01219	
	0.99%	21.00892	

Bootstrap p-values calculated from 5,000 replications

Given that the Sup LM tests indicate the validity of threshold co-integration between spot and futures price of natural gas. This implies that there is no arbitrage opportunity on futures contracts over a long period of time. Based on this finding, the threshold vector error correction model can be conducted for these variables. The results of threshold vector error correction model are presented in Table3.

Table III: Threshold Error Correction Model Result

Dependent Variables:	ΔLNSPOT		ΔLNFUT	
Variables	$w_{t-1} \leq \gamma$	$w_{t-1} > \gamma$	$w_{t-1} \leq \gamma$	$w_{t-1} > \gamma$
w_{t-1}	-0.457662	-3.162488[a]	0.298804	-2.294017[a]
Constant	-0.008640	0.086079[a]	-0.008625	0.068867[a]
$LNSPOT_{t-1}$	-0.982129[b]	0.324838[c]	-1.362549[a]	0.208770
$LNFUT_{t-1}$	0.980012[c]	-0.006601	1.421371[a]	0.099851
γ	0.01324281			
% of Observations	43.8	56.2		

The p-values are calculated by using with the heteroskedasticity-consistent(Newey-West) standard errors.
[a], [b] and [c] indicate a 1%, 5% and 10% level of significance, respectively.

The results of Table 3 suggest that the estimated threshold is 0.01324281. While the error correction terms are statistically significant in second regimes of spot and futures price equations, error correction terms in the first regime are statistically insignificant. This findings indicate that adjustment will occur in the second regime.

The next step of the empirical analysis is to investigate the causality relationship between spot and futures price, using the threshold granger causality test proposed by Li (2006). Table 4 presents the test results.

Table IV: Granger Causality Test Results

	H_0^0	H_0^1	H_0^2
LNSPOT - LNFUT	6.057155[b]	6.056832[b]	0.000323
LNFUT - LNSPOT	14.21032[a]	13.79322[a]	0.417101

[a] and [b] indicate a 1% and 5% level of significance, respectively.

As can be shown in Table 4 we find that there is a bi-directional causality between Natural gas spot and futures prices in the first regime. These findings are interpreted that Natural gas spot and futures prices are jointly determined and affected, except

when the threshold parameter exceed 0.01324281. This results suggest that there is no profitable arbitrage opportunity exists.

4. Conclusion

This study has examined the casual relationship between natural gas spot and futures prices. The analysis based on monthly data from January 2000 to November 2012. As a first stage of our analysis, we determined the order of integration of these variables by using ADF, PP, KPSS and Ng-Perron tests. Given that the integration of these two series is of the same order, we investigate validity of threshold co-integration between spot and futures price of natural gas by using sup LM test which developed by Hansen and Seo (2002). We find that there is a threshold cointegration relationship between spot and futures prices of natural gas. The final stage of our analysis is to investigate the causality relationship by using the threshold granger causality test proposed by Li (2006). We concluded that there is a partially bi-directional causality between Natural gas spot and futures prices. When threshold parameter does not exceed the threshold value Natural gas spot and futures prices are jointly determined. The evidence obtained from this paper also suggests that there is information flow between natural gas spot and future market and there is no profitable arbitrage opportunity exists.

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