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Research on the Linkage Effect of Natural Gas Price

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Abstract

In this paper, we develop a vector error correction model for US natural gas market. It allows us to analyze the linkage effect of the natural gas price from 1998 to 2016. In particular, we prove the evidence that there is a long-term equilibrium relationship in US natural gas, coal and crude oil prices. Impulse response function and variance decomposition are used to examine the linkage effects that a shock in coal and crude oil price would have on natural gas price.

Keywords: Natural gas price; VEC model; Impulse response; Variance decomposition.

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1. Introduction

As natural gas accounts for a growing proportion in the world's energy consumption, a heat debate has arisen over the linkage effect of the natural gas price. It seems that when coal price and crude oil fluctuate in a period, the natural gas price will fluctuate correspondingly. It is possible that a certain relationship between gas, coal and crude oil could exists. The paper use a systematic time-series approach, including VEC model analysis [1], impulse response analysis [2] and variance decomposition [2], combining the software Eviews8.0 to explore the linkage effect between natural gas price and coal, crude oil prices.

2. Methodology

2.1. VAR/VEC model

Given a vector of Y_t including k selected variables, a VAR model can be expressed as follows [3]:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + BX_t \quad (1)$$

If cointegration among variables of Y_t, a VEC model can be further specified as follows:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + BX_t + \varepsilon_t \quad (2)$$

$$\Pi = \sum_{i=1}^{p} A_i - I, \Gamma_i = -\sum_{j=i+1}^{p} A_j$$

Eq. (2) represents the first differences of VAR model, where Δ is the difference operator ($\Delta Y_t = Y_t - Y_{t-1}$). Coefficients in matrix $\Pi = \alpha\beta'$ contain information on the long-term cointegration relationship. Specifically, β is the cointegration vector and α indicates the adjustment speed of each variable in response to deviation from the cointegrating relationship. Γ_i is the coefficient matrix measuring the short-run dynamics, X_t is exogenous variable, and ε_t is a vector of innovation.

2.2. Unit Root and Cointegration Tests

For unit root test, there is Augment Dickey-Fuller Test [4], which the null hypothesis is the series has no unit root that means the series is non-stationary. Two methodologies can be used to test for cointegration. One is Engle-Granger test [5] for two variables, the other is the trace test for multivariate developed by Johansen [6].

3. Empirical Analysis

The paper use the natural gas price of the Henry trading center: GP_t (*$/MMBtu*), the crude oil price of West Texas Intermediate: WTI_t (*$/barrel*) and the US coal spot price index: CP_t (*$/ton*) from 1998 to 2016. These energy prices can be obtained from the DRCNET Statistical database [7]. Fig.1 presents the result. Intuitively, we can see that there is a certain relationship between the three price series, and they are nonstationary.

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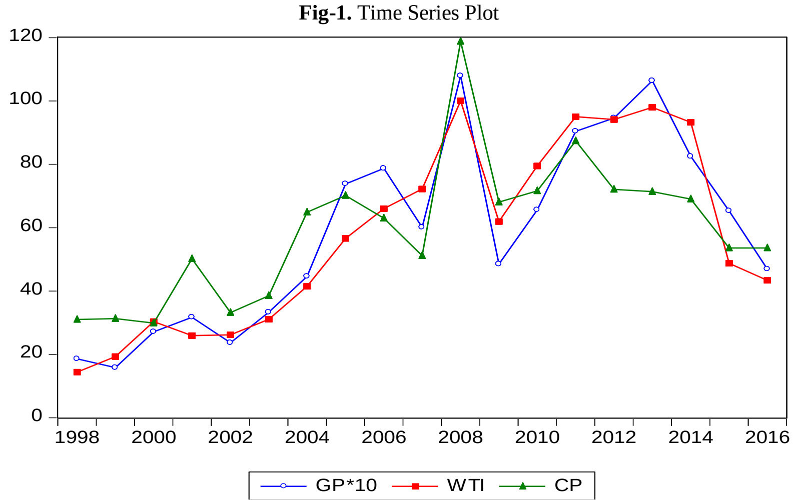
Fig-1. Time Series Plot



3.1. Unit Root Test

After the first-order difference, the values of ADF test statistic of $d(GP_t)$, $d(CP_t)$ and $d(WTI_t)$ are -5.89, -6.28, -4.77, and P value are approximately 0. Therefore, when the level of significance $\alpha = 0.05$, the null hypothesis should be rejected. It is considered that the first difference series are stationary. That is to say the original series GP_t, CP_t and WTI_t are $I(1)$. The results of the ADF test of the first-difference series $d(GP_t)$, $d(CP_t)$ and $d(WTI_t)$ are as follows:

Table-1. ADF test of $\boldsymbol{d(GP_t)}$

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.892806	0.0010
Test critical values:	1% level	-4.616209	
	5% level	-3.710482	
	10% level	-3.297799	

Table-2. ADF test of $\boldsymbol{d(CP_t)}$

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.275975	0.0007
Test critical values:	1% level	-4.667883	
	5% level	-3.733200	
	10% level	-3.310349	

Table-3. ADF test of $\boldsymbol{d(WTI_t)}$

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.769973	0.0076
Test critical values:	1% level	-4.616209	
	5% level	-3.710482	
	10% level	-3.297799	

3.2. Cointegration Test

We consider the variable $Y_t = (GP_t, CP_t, WTI_t)'$ and establish VAR(2) model. The largest eigenvalue test statistic shows that there is one cointegration relationship at the 5% significance level. The cointegration equation is:

$$GP_t = 0.36CP_t - 0.132WTI_t + \hat{\mu}_t$$
$$\text{standard error} = (0.03975)\ (0.02723) \qquad (3)$$

From the estimated equations, we know that there is a long-term equilibrium relationship between natural gas, coal and oil prices. And coal prices have a positive effect on natural gas prices. As the coal price index rose by 1%, the natural gas price rose by 0.36% accordingly. We can further get the VEC model.

The VEC model is estimated as follows:

$$\Delta Y_t = \begin{pmatrix} 0.18 \\ -0.09 \\ -0.15 \end{pmatrix} + \begin{pmatrix} -0.53 & -0.11 & 0.12 \\ -7.72 & -0.72 & 1.15 \\ 3.24 & -1.49 & 0.39 \end{pmatrix} \Delta Y_{t-1} + \begin{pmatrix} -0.41 & -0.02 & 0.05 \\ -13.07 & -0.04 & 1.70 \\ 0.09 & -0.67 & 0.57 \end{pmatrix} \Delta Y_{t-2} + \begin{pmatrix} -0.18 \\ 1.36 \\ -3.57 \end{pmatrix} VECM_{t-1} + \hat{\varepsilon}_t$$

$Y_t = (GP_t, CP_t, WTI_t)'$ (4)

$$VECM_t = GP_t - 0.36CP_t + 0.132WTI_t + 8.14 \qquad (5)$$

Table-4. Cointegration test

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.919211	40.25470	21.13162	0.0000
At most 1	0.538439	12.37025	14.26460	0.0975
At most 2 *	0.285801	5.385493	3.841466	0.0203

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table-5. Cointegration equation

1 Cointegrating Equation(s): Log likelihood -126.9160

Normalized cointegrating coefficients (standard error in parentheses)

GP	CP	WTI
1.000000	-0.363782	0.132086
	(0.03975)	(0.02723)

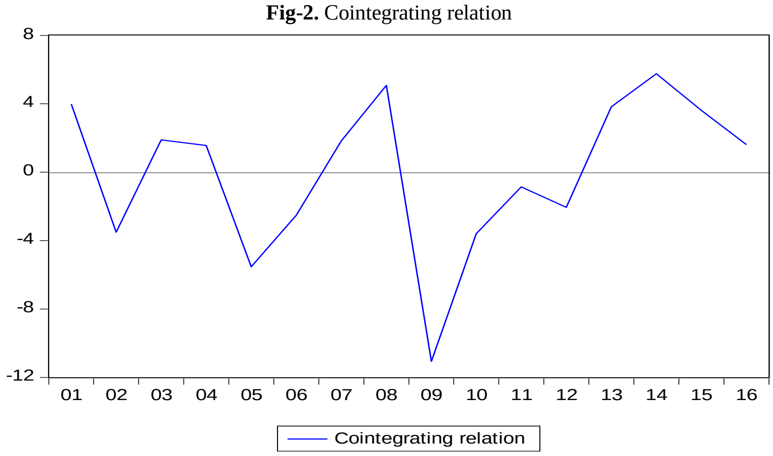
Adjustment coefficients (standard error in parentheses)

D(GP)	-0.179984
	(0.30440)
D(CP)	1.364065
	(2.43064)
D(WTI)	-3.569401
	(2.22323)

4. VEC Model Analysis

The line of zero-mean represents the long-term equilibrium stability relationship between the three variables of natural gas, coal, and oil prices. The absolute value of the error correction term is larger relatively between 2008 and 2009, indicating that short-term fluctuations deviated from long-term equilibrium during this period, which may be due to the impact of the global financial crisis in 2008. After about three or four years of adjustment, from 2011 to 2012, it has returned to a long-term equilibrium and maintained stability, which may be related to the slowdown of the financial crisis and the economic recovery. Fig. 2 Presents the cointegration curve (i.e., curve of error correction term).

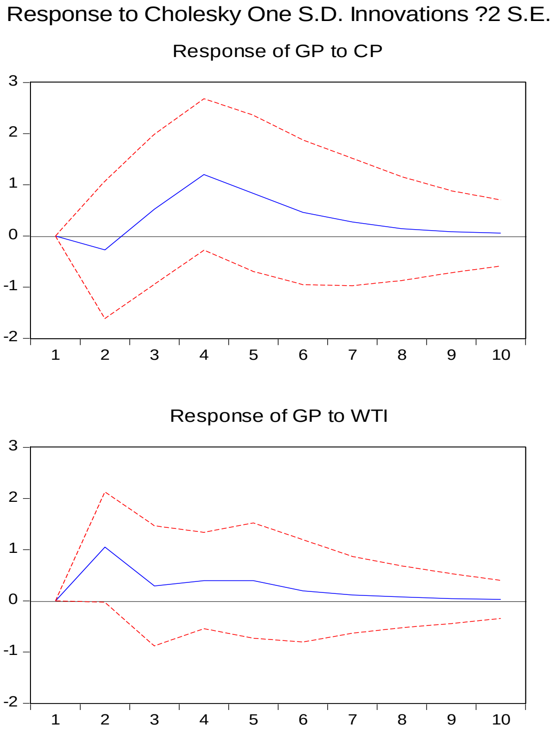
Fig-2. Cointegrating relation



4.1. Impulse Response Analysis

The natural gas price does not response immediately to the shock of coal price. The response in first phase is 0, and in second phase is about 0.3 and is negative. The natural gas price in fourth stage has the largest response to coal price, which is about 1.0 and is positive. After that, the responses tends to zero around in eighth period. And the natural gas price also does not response immediately to the shock of WTI price. Natural gas price has the largest response to WTI price in second phase, which is about 1.0 and is positive, and then this response declines. Around in the seventh period, the response dies out stably. Fig.3 presents the response of a shock of coal and oil prices on natural gas prices.

Fig-3. Impulse response function



4.2. Variance Decomposition

Table 6 shows that in the first-phase forecast, the natural gas price forecast variance is entirely caused by the disturbance of itself. After two periods, the forecast variance of natural gas price has 79.07% caused by the disturbance of itself, 4.73% by the coal price and 16.20% by the WTI crude oil price. As the forecast period goes by, the part of the forecast variance caused by coal and crude oil price disturbances increases, and the part caused by self-disturbance decreases but still accounts for a large percentage. After about 8 periods, the results of natural gas price decomposition are basically stable. About 59.9% are caused by the own price fluctuations, 25.7% by coal price fluctuations, and 14.4% by WTI crude oil price fluctuations.

Table-6. Variance decomposition

Variance Decomposition of GP: Perio...	S.E.	GP	CP	WTI
1	1.988679	100.0000	0.000000	0.000000
2	2.387463	79.34715	1.299440	19.35341
3	2.708746	79.06647	4.732731	16.20079
4	3.087330	67.08681	18.79191	14.12127
5	3.234151	61.89729	23.74021	14.36250
6	3.277083	60.55529	25.10139	14.34331
7	3.292221	60.10929	25.55385	14.33686
8	3.296769	59.97807	25.66955	14.35238
9	3.298375	59.93958	25.70509	14.35533
10	3.299154	59.92167	25.72261	14.35572
11	3.299512	59.91282	25.73105	14.35613
12	3.299669	59.90885	25.73493	14.35622
13	3.299738	59.90708	25.73668	14.35624
14	3.299765	59.90634	25.73739	14.35627
15	3.299776	59.90605	25.73767	14.35628
16	3.299781	59.90594	25.73778	14.35628
17	3.299783	59.90589	25.73783	14.35628
18	3.299784	59.90587	25.73785	14.35628
19	3.299784	59.90586	25.73786	14.35628
20	3.299784	59.90586	25.73786	14.35628

5. Conclusions

The paper provides evidence that the American natural gas prices are cointegrated with coal and crude oil prices by the Johansen methodology. We generated impulse function to investigate the response of natural gas price as a result of a shock introduced in the price of coal and crude oil, and the response from natural gas seems to die out quickly. And we used the variance decomposition to investigate the contribution of each innovation shock to endogenous variables. After 8 periods, the results of natural gas price variance decomposition are basically stable, the contribution degree of coal and WTI crude oil price are 25.7%, 14.4% respectively.

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