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The asymmetric effect of coal price on the China's macro economy using NARDL model

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Abstract. The present work endeavors to explore the asymmetric effect of coal price on the China's macro economy by applying nonlinear autoregressive distributed lag (NARDL) model for the period of January 2005 to June 2015. The obtained results indicate that the coal price has a strong asymmetric effect on China's macro economy in the long-run. Namely one percent increase in coal price leads to 0.6194 percent of the China's macro economy increase; and while the coal price is reduces by 1 percent, the China's macro economy will decrease by 0.008 percent. These data indicate that when coal price rises, the effect on China's macro economy is far greater than the price decline. In the short-run, coal price fluctuation has a positive effect on the China's macro economy.

1. Introduction

Due to the characteristics of China's energy structure—"rich coal, lean oil, less gas", the proportion of coal in primary energy production and consumption structure is more than 65% for a long time. Although the China is vigorously developing new energy and clean energy in recent years, it is difficult to improve, as the coal counts for a large proportion in energy production and consumption in the short term, lacking for other new energy resources system, immature new energy technology and imperfect new energy structure system. However, as the upstream industry of the national economy, the price fluctuations of coal is bound to price fluctuations effect of the market of the means of production, which directly leads to fluctuations in the cost of downstream industry and have an impact on the market operation and the general price level. Finally, it has an impact on the economic development of our country. Therefore, studying the influence of coal price on China's macro economy pay the role of a guide when improving coal enterprises and promote sustainable economic development.

In available literature, the CGE model, VAR model, impulse response function and other methods or models have been applied to study from different perspectives. For example, Gu Xiaohui used VAR model, Cointegration test and Granger causality test to analyze the impact of the coal, the international oil prices internationally on the price level (PPI,CPI), industrial added value (VAI) and monetary circulation [1]. Lin Boqiang, Mou Dunguo studied the effects of oil and coal prices on Chinese macro economy by CGE method [2]. Zhou Aiqian analyzed the reflect of the various sectors of the national economy on the coal price's changes by using input-output model and VAR's impulse response function [3]. Ding Zhiguo applied multiple

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econometric methods, Granger causality test, VAR model, ECM model and Impulse Response Function, etc. to make some general test to the conduction effect of coal price to the aggregates of entity economy, then used parameter-varying state spatial model to measure its time-varying efficiency [4]. Wang Lizhi and Gao Zhiyuan used CGE model to study the impact of coal price decline on China's macro economy [5]. Under the linear and nonlinear double perspective, Li Wenbo used Zou's test, Granger causality test and impulse response function, etc to quantitatively analyzed the influence of coal price fluctuation on China's economic growth[6]. However, domestic literature rarely recognizes that the impact of coal price on the macroeconomic isn’t necessarilylinear, maybe it is nonlinear. In addition, because of the oil - based foreign energy characteristics, most of them are based on energy prices or oil prices as a research center. For example, Jammazi studied the relationship between international crude oil price and exchange rate based on the wavelet-based NARDL model [7].

How strong the impact of fluctuations in coal price bears on China's macro economy? Is the relationship between them linear or nonlinear? In order to solve these problems, this paper explores the asymmetric effect of coal price on the China's macroeconomic by applying NARDL model proposed by Shin from two levels of the long-run and short-run [8]. Then, we analyze the reasons behind it, and provide scientific evidence for improving coal enterprises and promoting the balanced development of China's economy.

2. Model and data

2.1 Nonlinear autoregressive distributed lag (NARDL) model

The NARDL model explores the long-run and short-run asymmetrical relationship between the non-stationary time series using a formula. Therefore, the NARDL model is suitable for the study and analysis the relationship between coal price and China's macro economy.

According to the theory of Granger and Johansen [9,10], we can construct the dynamic relationship between variables by using error correction model (ECM). Therefore, we can use linear ECM to describe the long-run and short-run effects of coal price on China's macro economy (GDP) under the assumption that there is no asymmetric cointegration.

$$\Delta Lgdp_t = \mu + \rho Lgdp_{t-1} + \delta Lp_{t-1} + \sum_{i=1}^{p-1} \alpha_i \Delta Lgdp_{t-i} + \sum_{i=0}^{q-1} \omega_i \Delta Lp_{t-i} + \varepsilon_t \tag{1}$$

Where, Lgdp=log(gdp), Lp=log(p), Δ=first difference, p represents maximum lag order number of Chinese macro Economy. And q represents maximum lag order number of Coal Price. We can see the long-run and short-run relationship between coal price and China's macroeconomic by Equation (1), but the formula is not suitable for the existence nonlinear relationship of two variables. In consequence, this paper applies NARDL model proposed by Shin which can be very precise description of the asymmetric effect of coal price on the China's macroeconomic from two levels of the long-run and short-run [9]. Taking the coal price as an exogenous variable and decomposing it into the two parts: the accumulation sum of positive impact and the accumulation sum of negative impact, representing increases and decreases.

$$\begin{aligned} P_t^+ &= \sum_{j=1}^{t} \Delta P_j^+ = \sum_{j=1}^{t} \max\left(\Delta P_j, 0\right) \\ P_t^- &= \sum_{j=1}^{t} \Delta P_j^- = \sum_{j=1}^{t} \min\left(\Delta P_j, 0\right) \end{aligned} \tag{2}$$

According to the theory proposed by Shin, we can construct the asymmetric correction error model to explain the long-run and short-run asymmetric relations between the two variables through Equation (1) and Equation (2).

$$\Delta Lgdp_t = \mu + \rho Lgdp_{t-1} + \delta^+ Lp_{t-1}^+ + \delta^- Lp_{t-1}^- + \sum_{i=1}^{p-1} \alpha_i \Delta Lgdp_{t-i} + \sum_{i=0}^{q-1} \left(\omega_i^+ \Delta Lp_{t-i}^+ + \omega_i^- \Delta Lp_{t-i}^-\right) + \varepsilon_t \tag{3}$$

To validate a cointegrated and asymmetric relationship using the ARDL Bounds test approach, we used the Bound-coefficient test[12]. In the test, the significance of the associated variables was ascertained by jointly setting ρ=δ+=δ-=0, δ+=δ- . The long-run asymmetric coefficients in Equation (3) is tied by the following relationships: LP+=-δ+/ρ; LP-=-δ-/ρ.

2.2 The data

This paper selects the monthly data January from 2005 to June 2015 for analysis in China. For the coal price we make use of the coal mining and washing prices index with the data from the China Economic Information Network (http://cyk.cei.gov.cn/aspx Default.aspx). And we use Gross Domestic Product (GDP) on behalf of the Chinese macro economy whose the quarterly data is from National Database. To make use of quarterly data of GDP, we need to process it into the monthly data. Firstly, we adopt the monthly data of the industrial added value (Industrial added value of the monthly data from the national research network, which for the lack of the number of each year in January of the same period of the previous year, we use interpolation method to get) for processing quarterly data of GDP, and then calculate the weight of the industrial added value of each month. Ultimately, monthly GDP data can be calculated. To convert the data into 2005 as a fixed base data. In order to reduce the fluctuation, we take the natural logarithm for the GDP and the coal price variables respectively recorded as LP and LGDP.

3. **Empirical analysis**

3.1 Unit root test

The unit root test results using Augmented Dickey–Fuller test and Phillips–Perron test are shown in Table 1. It can be found that all the price series have unit root at their level values, but at their first difference they become stationary, namely LGDP～I(1), LP～I(1).

Table 1. Unit root test results of ADF test and PP test

Test sequence	ADF		PP	
	T- Statistics	Prob.	T- Statistics	Prob.
LGDP	-1.381887	0.8612	-0.907524	0.9511
ΔLGDP	-4.080820[a]	0.0015	-60.4224[a]	0.0001
LP	-1.739467	0.4088	-1.652080	0.4531
ΔLP	-4.773595[a]	0.0000	-10.07735[a]	0.0000

Note: a, b, c represent significance at 1%, 5% and 10% level respectively.

3.2 Granger Causality test

In order to determine the relationship between coal price and the Chinese economy, we use eviews9.0 software to carry out the Granger causality test. Because the variables lag length (m) is arbitrary in the regression model, so we respectively selected lag order about 2 or 4 in order to ensure that the test results are not affected by lag length (m).

Table 2. Results of Granger causality test for multiple lag lengths

null hypothesis	Lag Length	F- Statistics	Prob.	Judgment
LP $\nrightarrow$ LGDP	2	10.1080	0.0000[a]	Refuse
LGDP $\nrightarrow$ LP	2	3.73874	0.0266[b]	Refuse
LP $\nrightarrow$ LGDP	3	18.4825	0.0000[a]	Refuse
LGDP $\nrightarrow$ LP	3	3.25089	0.0244[b]	Refuse
LP $\nrightarrow$ LGDP	4	16.2745	0.0000[a]	Refuse
LGDP $\nrightarrow$ LP	4	5.25153	0.0006[a]	Refuse

Note: a, b, c represent significance at 1%, 5% and 10% level respectively.

From the analysis results in Table 2, in the 5% significant level, there is a two-way Granger causality between LP and LGDP, which shows that the economic growth of China is not only affected by the change of the coal price from 2005 to 2015; In contrast, the coal price also constrained by China's economic growth in a certain extent. The factors include that energy is a prerequisite for the development of the national economy and China depends on long-term energy consumption to promote the development of economy.

3.3 Empirical results using NARDL

Before using the NARDL model, it is necessary to ensure the lag order number of the time series used in Equation (3). Pesaran *et al.* recommended the use of SBC criteria or AIC criterion, so we use the AIC criterion which most of the literature are used to determine the lag order number of the variables in the model. At the same time, taking into account the length of the data, we found that the model is suitable for the lag order number (p,q)=(3, 2).

Table 3. Results of the NARDL model

Regressors	coefficient	Prob.
C	1.658252	0.0000
LGDP(-1)	-0.327212	0.0000
$LP^+(-1)$	0.202686	0.0000
$LP^-(-1)$	0.002629	0.9393
DLGDP(-1)	0.194328	0.0041
DLGDP(-2)	-0.018022	0.7790
DLGDP(-3)	0.148820	0.0217
DLP^+	1.995196	0.3718
DLP^-	1.285200	0.6779
$DLP^+(-1)$	-0.286816	0.9262
$DLP^-(-1)$	-1.366430	0.7503
$DLP^+(-2)$	-0.913357	0.6822
$DLP^-(-2)$	1.277002	0.6820
Test of Cointegration （$\rho=\delta^+=\delta^-=0$）	15.41418[a]	
Test for Asymmetry （$\delta^+=\delta^-$）	6.340519[a]	
R-Squared	0.199136	
Log likehood L	295.4183	

Wald test: a, b, c represent significance at 1%, 5% and 10% level respectively.

Table 3 has shown the estimated results for asymmetry effect and the Prob. of the Wald test for coal price and GDP. The coefficient of coal plus (δ +) is significant at 5% level, but the coefficient of coal minus (δ-) isn't significant at 10% level. While the coefficient of coal plus was greater than the coefficient of coal minus. This indicates that the China's macro economy reacts with a higher magnitude when coal price increases than when price decreases. Calculation of the asymmetric effect coefficients of the coal price increase and decrease, respectively, on the Chinese macro economy in the long-run: LP+=-δ+/ρ=-0.202686/-0.327212=0.6194, LP-=-δ-/ρ=-0.002629/-0.327212=0.0080. The significance of the difference of these two coefficients was again tested using the Wald test and the null hypothesis of equality of the co-efficient could not be rejected at the 1% level. Thus the impact of coal price changes on the increase and decrease of GDP was statistically significant.

The significant asymmetric effect of coal price on the China's macro economy is mainly caused by the following reasons. In the heavy chemical industry development stage, secondary industry remains the leading industry of our national economy, and is limited to the China's energy characteristics—"rich coal, lean oil, less gas". Thus, the China's economic growth to a large extent depends on the consumption of coal. However, as the upstream industry of the national economy, the rise in price may improve the price level of the means of production market and led directly to the growth of downstream industry costs. Thus, it promotes the rise of the price level of the whole national economy. However, the increase in coal price will bring negative influence to the related industries to consumption of coal, which can offset part of the positive impact of rising coal prices on the economy. Overall, the increase in coal price pays a certain stimulating role in our country economy. When the decline in coal prices, as the downstream industry of coal industry chain, the large changes in output of mining industry, construction etc. to a large extent contributed to the growth of these industrial economies. But industries related to the lesser extent of Coal Industry have small changes in output, such as agriculture, forestry, animal husbandry, fishery, services, etc.. Therefore, the positive impact of the consumption of coal based on industries greatly offset the negative impact of the decline in coal prices on the economy.

For the short-run effect, a 1% increase in coal price has respectively changed 1.995%, -0.287% and -0.913% of GDP current, first and second, the overall effectiveness: 0.795%. That is, the increase of coal price has a short-term positive effect on GDP. 1% decrease in coal price, GDP current, first and second respectively change 1.285%, -1.367% and 1.277%, the overall effectiveness: 1.195%. Thus the decrease of coal price has a short-term positive effect on GDP. Generally speaking, fluctuations of coal price have short - run positive effects on GDP in China.

4. Conclusions and suggestions

This paper uses the NARDL model to analyze the asymmetric effect of coal price on China's macro economy from January 2005 to June 2015. And get the following conclusions and suggestions:

There is a two-way Granger causality between LP and LGDP, which shows that the economic growth of China is not only affected by the change of the coal price from 2005 to 2015; in contrast, the coal price also constrained by China's economic growth to a certain extent. The economic growth is influenced by coal price, which is consistent with the irreplaceable of energy in the development of the productive factors, especially the energy characteristics of “rich coal, lean oil, less gas”. For many years, China's economic growth has consumed a large amount of energy, which is contrary to the sustainable development strategy of China's economy. Therefore, our country should actively adjust the industrial structure and accelerate economic growth mode from extensive to intensive type.

There is a long-run asymmetric relationship between coal price and China's macroeconomic. The fluctuation of coal price has a positive effect on GDP, but the sharp rise in price leads directly to the cost growth of downstream industry. And the enterprise will maximize the pursued profits by raising price, which even causes cost-push inflation and recession. The continued decrease of coal price would bring about decline of prices and economy and have a strong impact on the economy. Therefore, we should properly control the coal price to avoid frequent fluctuations which can actively promote the growth of our economy.

In the short term, coal price fluctuation has a positive effect on China's macro economy. Although fluctuations in coal price have a positive effect on China's economic in the short term, we should take some method as far as possible to avoid frequent volatility from the long-term perspective, such as increasing energy control means, establishing and improving the coal storage system.

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