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Coal price foam measurement based on SADF and GSADF

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Abstract: *This paper uses the methods of SADF and GSADF to test and measure the foam of China's thermal coal price. It is found that there were four significant foam in China's thermal coal price from January 2014 to February 2022. The main reasons are that the coal market is poor in recent years, the downstream demand is greatly reduced, the overcapacity, the rapid development of new energy and the macro policy changes. In view of the above reasons, from the perspective of the government, we should establish an early warning mechanism, implement steady regulation and control, and strictly control the port inventory in order to ensure the good development of the coal price market.*

Keywords: *Coal price; Price foam; SADF; GSADF*

1. Introduction

Coal is an important power fuel and industrial production raw material that affects national production and resource allocation, and coal price is the most direct factor that reflects the change of coal supply and demand. When there is a foam in coal prices, it means that there are certain problems in the coal market. Analyzing the reasons behind the foam in coal prices and formulating corresponding countermeasures can effectively help the coal industry escape from the price crisis and develop steadily.

Domestic scholars have studied the factors affecting the fluctuation of coal price in different aspects. Mu Dunguo et al. (2012) found that industrial added value and power consumption have a positive pulling effect on coal price based on time-varying parameter vector autoregression (tvp-var) [1]. Xie Shouxiang et al. (2006) found that the fluctuation of coal demand is the Granger cause of price fluctuation, and the price rise mainly depends on the increase of short-term demand [2]. Hu Yanbing et al. (2022) found that China's coal price is greatly affected by its own seasonal supply and demand relationship [3]. Tan Zhanglu et al. (2009) found that the coal price in China is mainly affected by the demand of downstream products and the international market price [4]. Ma Yan et al. (2021) found that the factors affecting the price of thermal coal are mainly natural gas production, the number of coal mining enterprises and thermal power generation [5]. Zhang Jianying (2016) found that coal prices are mainly affected by their own fluctuations, followed by commodity prices, macroeconomic prosperity index and coal production [6]. Cai Xinlei (2008) found that policy cost and supply-demand relationship are the main factors affecting coal price at present [7]. Wang Jian (2021) thinks that the impact of the epidemic on coal supply and demand is quite different [8]. Under the background of imbalance between supply and demand and sharp drop in international oil prices, coal prices will continue to be under pressure in the future. In addition, Zou Shaohui et al. (2022) used Monte Carlo method to test the fit of multiple coal price change models, and predicted the change of China's coal price before 2030 according to the test results [9]; Chen Chunzhao et al. (2021) established a VAR model to predict the coal price under emergency conditions [10]; Rao Shijie et al. (2021) established an RBF prediction model to predict the trend of coal prices in different times and situations[11].

To sum up, the existing research focuses on the study of influencing factors of coal price with VaR, VEC and grey model on the one hand, and on the prediction of coal price on the other. There are few studies on the measurement and cause analysis of coal price foam, and there is a lack of effective judgment on coal price foam. Therefore, this paper first uses SADF and GSADF to test the coal price foam from January 2014 to February 2022 respectively; Secondly, the time point of foam is detected and analyzed, and the causes of foam of coal price are explored from many angles; Finally, the paper puts forward relevant suggestions to prevent the emergence of foam, in order to help the coal market to achieve orderly and good operation.

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2. Foam test model

2.1 Foam test based on SADF

In order to solve the problem that the ADF test cannot find the periodic foam of assets, Phillips et al. Proposed the SADF test method. Unlike the traditional left tailed unit root test, SADF is based on the right tailed test. Consider recursive least squares estimation autoregression:

$$x_i = \mu + \rho x_{r-1} + \varepsilon_i \tag{1}$$

Subtract xt-1 from both sides to obtain:

$$\Delta x_i = \mu + (\rho - 1)x_{r-1} + \varepsilon_i \tag{2}$$

In formulae (1) and (2), $\varepsilon_i \sim i.i.d\ N(0, \delta^2)$. Different from the alternative hypothesis (left tail) H1: ρ＜1 of the traditional ADF test, the alternative hypothesis (right tail) of SADF test is H1: ρ＜1, where ρ=1+c/kn, c＞0, kn→∞, kn/n→0, k is the lag order, n is the number of samples. If the alternative hypothesis is accepted, there will be a slight explosion before or after the unit root, and the asset price foam will be detected.

SADF method extends forward through rolling test, so it can effectively find periodic foam and determine the specific time of foam. When t 6 the critical value again, the coal price will return to the reasonable price range.

SADF method judges the existence of foam through recursive rolling regression and sequential unit root test: starting from the initial observation value, determine the minimum estimated window width, extend forward in order to expand the sample size to form sub samples, and perform ADF test in sequence (the test value is recorded as $ADF_{r_2}^{r_1}$, r_1 and r_2 are the proportion of the starting and ending sample size to the total sample size respectively), Until the sample window r_w is expanded from the minimum window width r_0 to the full sample 1, that is, the sub sample is expanded to the sample population. Then calculate and construct the SADF statistic sequence, and Phillips et al defined the SADF statistic as $SUP_{r_2 \epsilon [r_0,\ 1]} ADF_0^{r_2}$, (recorded as SADF); Compare the maximum value of SADF statistic with the critical value to determine whether to accept the original hypothesis and judge the explosiveness of foam and the time of formation and bursting of foam. The original hypothesis H0 represents that the real process is a random walk without drift,

SADF statistic distribution:

$$SUP_{r_w \epsilon [r_0,\ r_1]} \left\{ \frac{r_w\left[\int_0^{r_w} W dW - \frac{1}{2} r_w\right] - \int_0^{r_w} W dr . W(r_w)}{r_w^{\frac{1}{2}} \left\{ r_w \int_0^{r_w} W^2 dr - \left[\int_0^{r_w} W(r) dr\right]^2 \right\}^{\frac{1}{2}}} \right\} \tag{3}$$

2.2 Foam test based on GSADF

SADF test has excellent performance and is very effective in testing single foam; However, when there are multiple foam in the samples with a large time span, the non-uniformity problem will lead to the weakening of its testing ability. In order to make up for this deficiency, Phillips et al. Put forward GSADF test method [12].

Unlike the SADF test, the GSADF sets the test start point to move forward sequentially, the overall regression process consists of: $r_1 = 0$ extended to $r_1 = 1 - r_w$: the starting point of the first observation sample is not fixed, and the sample sequence is expanded by changing the starting point r_1 and the ending point r_2 through a flexible and feasible window width. Regression: from the first observation when $r_1 = 0$ to the last observation when $r_1 = 1 - r_w$, obtain ρ sequence of ADF test values (recorded as $ADF_{r_w}^{r_1}$) is the GSADF sequence. The GSADF statistic is defined as the maximum ADF statistic value of the optimal window r_w and the optimal starting point r_1 within the feasible variation range, namely:

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$$GSADF = SUP_{r_w \epsilon [r_0,\ r_1]} \left\{ SUP_{r_w \epsilon [0,\ 1-r_w]} ADF_{r_w}^{r_1} \right\} \tag{4}$$

The original hypothesis H0 also indicates that the real process is a random walk without drift, and the asymptotic distribution of GSADF statistics is:

$$SUP_{r_w \epsilon [r_0,\ 1]} SUP_{r_w \epsilon [0,\ 1-r_w]} \left\{ \frac{r_w \left[\int_{r_1}^{r_2} W dW - \frac{1}{2} r_w \right] - \int_{r_1}^{r_2} W dr . [W(r_2) - W(r_1)]}{r_w^{\frac{1}{2}} \left\{ r_w \int_{r_1}^{r_2} W^2 dr - \left[\int_{r_1}^{r_2} W dr \right]^2 \right\}^{\frac{1}{2}}} \right\} \tag{5}$$

In formula (5), $r_2 = r_1 + r_w$. In fact, the SADF test can be considered as part of the GSADF test. Phillips et al. (2012) pointed out that GSADF test was more accurate than SADF test, expanded the sub sample size, and was more excellent in testing multiple continuous foam, which could effectively test data with moderate fluctuations. The asymptotic critical values of SADF and GSADF tests were obtained by Monte Carlo simulations.

3. Empirical analysis

3.1 Data selection and descriptive statistics

Coal is a bulk commodity. In this paper, the price of thermal coal is selected as the coal price. The data is from the China Economic and Trade Commission industrial database. The selected inspection period is from January 2014 to February 2022. The price trend and characteristics of thermal coal in China can be obtained as shown in Figure 1.

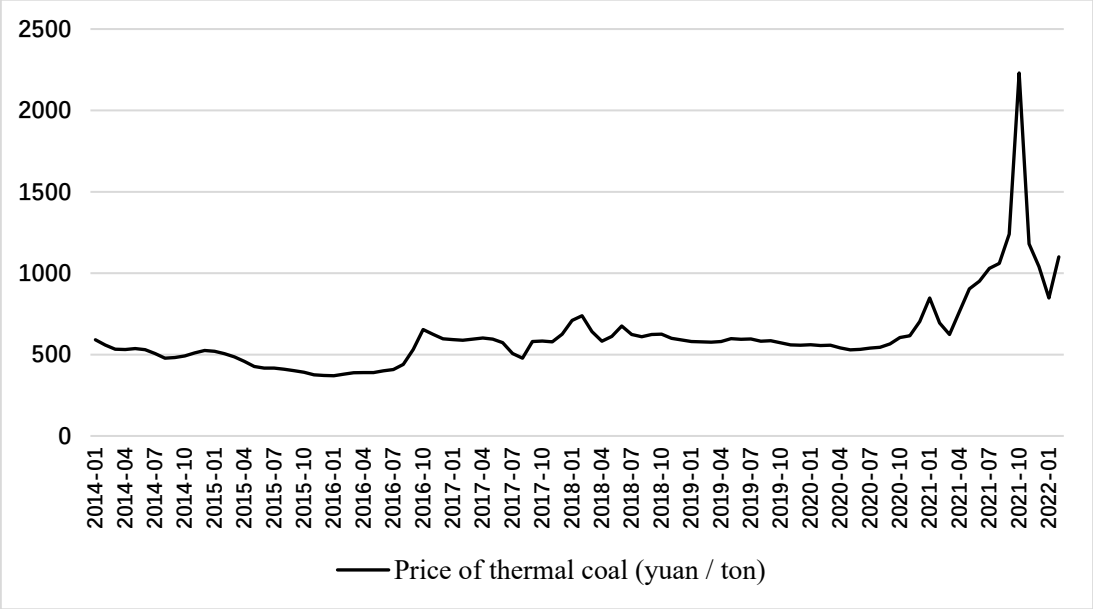

Figure 1: Price of thermal coal in China

From the price trend of thermal coal in Fig. 1, it can be seen that from 2014 to 2020, the price of thermal coal was relatively stable, fluctuating around 500 yuan / ton. From January 2021 to October 2021, the price of thermal coal continued to rise, and rose to 2230 yuan / ton in October 2021, then gradually decreased from October 2021 to January 2022, and rebounded in February 2022.

Table 1: Descriptive statistical results

	Mean value	Median	Maximum	Minimum value	Standard deviation	Observed value
Thermal coal price	611	578	2230	370	237	98

Table 1 shows the descriptive statistical results of this data set. It can be seen that during the period from January 2014 to February 2022, the maximum value of thermal coal price index is 2230 yuan /

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ton, the minimum value is 370 yuan / ton, and the standard deviation is 237. The difference between the maximum value and the minimum value is large, so it is necessary to carry out foam test.

3.2 Construction of inspection model

The traditional ADF test can not find the periodic foam of asset price and its specific duration. There may be multiple foam in China's thermal coal price during the observation period, and it is necessary to explore the time point of occurrence and bursting of foam, so as to judge the current market situation and policy effect. Therefore, this paper intends to use the SADF test and GSADF test in the recursive unit root test to detect the foam of China's thermal coal price; According to the method of determining the sequence minimum effective window proposed by Phillips et al., the selected estimated effective minimum window width is $r_0 = 10/98 \approx 0.1$, that is, the minimum window sample size is 10. Selecting Eviews 10.0 software, the test results are obtained through 2000 Monte Carlo simulations.

3.3 Foam detection

SADF and GSADF methods are used to detect the price of thermal coal. The results obtained through 2000 times of repeated simulation are shown in Table 2.

Table 2: SADF test and GSADF test of thermal coal price

	SADF	GSADF
	5.573***	8.332***
Finite sample critical values		
90% level	1.213	2.246
95% level	1.510	2.659
99% level	2.132	3.472

It can be seen from table 2 that the SADF and GSADF values of the data series are 5.573 and 8.332 respectively, while the critical values are 2.132 and 3.472 respectively at the significance level of 1%. Since 5.573 ＞ 2.132 and 8.332 ＞ 3.472, at the significance level of 1%, the original assumption H0: r = 1 is no unit root, there is an explosive sub period in the price of power coal, and there is a price foam in the power coal market.

3.4 Time point analysis of foam

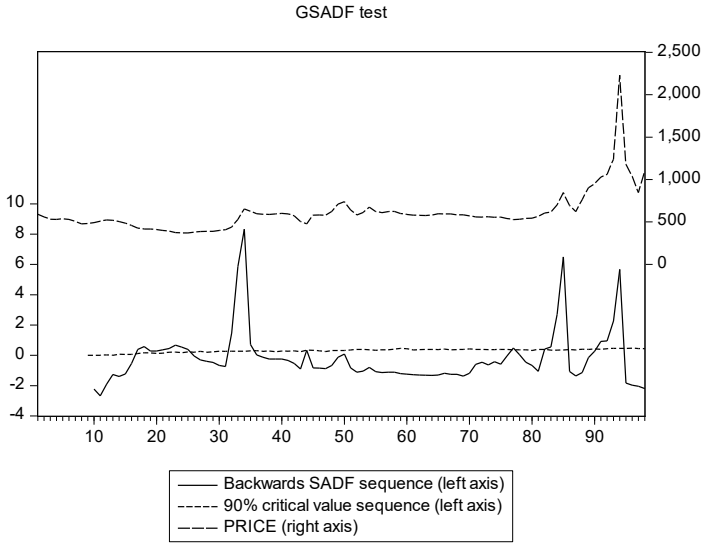

Figure 2: Foam range of thermal coal price in China

According to the GSADF test results, the foam estimation diagram of thermal coal price with 90% confidence interval is drawn as shown in Figure 2. The upper curve represents the critical value at the 90% confidence level, and the lower curve is the GSADF statistic to be changed. According to the foam test principle, when the GSADF statistic is greater than the critical value under the 90%

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confidence level, it indicates that there is a foam in the market. Therefore, it can be found that there are multiple foam in the price of Chinese thermal coal during the re inspection period.

The first foam came into being in January 2015 and lasted for 9 months before bursting in September 2015. Macroscopically, it is mainly due to the downturn of the international market economy and the obstruction of the development of the overall environment; From a micro perspective, it is mainly due to insufficient demand and overcapacity in the downstream of coal, and the squeeze of hydropower and other new energy. Since 2015, the total transportation volume of coal has decreased in both railway transportation and shipping, especially in railway transportation. The reduction of the total coal consumption in the downstream has led to the squeezing of the port. Facing the transportation cost accounting for nearly half of the coal cost, most enterprises choose to reduce coal output to reduce losses.

The second foam occurred in April 2016 and burst in August 2016 after 4 months. In 2016, the government vigorously implemented the coal capacity reduction policy, the enthusiasm of coal enterprises for investment weakened, and the coal price continued to fall. However, in the second half of 2016, the continuous contraction of the coal supply side led to the imbalance of domestic coal supply and demand, and the coal market was short of demand. The downstream coal enterprises filled the domestic coal gap by increasing the import of coal, which caused the coal price to rise significantly. The market got rid of the downturn and increased the profit space. The situation was significantly improved and the loss rate was reduced, large coal enterprises have gradually turned losses into profits.

The third foam occurred in June 2020 and burst in September 2020 after four months. In terms of coal consumption, China's coal consumption in 2020 increased by 0.6% year-on-year. According to the analysis and calculation of major coal consuming industries, coal consumption in the power industry, steel industry, building materials industry and chemical industry increased by 0.8%, 3.3%, 0.2% and 1.3% year-on-year respectively. In terms of coal supply, first, the domestic output increased, second, the import volume increased, and third, the coal transfer volume remained stable. In terms of coal storage, in 2020, the coal storage of coal enterprises decreased, the coal storage of major ports in the country also continued to decrease, and the coal storage of national unified dispatching power plants decreased. The inventory level was basically reasonable.

The last foam occurred in February 2021 and burst in June 2021 after five months. Due to the requirement of supply guarantee during the Spring Festival, most coal mining enterprises maintain normal production, but the downstream industrial enterprises are on holiday, and the demand decline causes the accumulation of inventory, which promotes the rapid decline of coal prices from high prices. After the Spring Festival, the demand recovered, the coal management ticket became stricter, and the coal price returned to the rising channel. At the same time, due to the frequent safety accidents, the price rise speed was further accelerated. In addition, in January 2022, the comprehensive work plan for energy conservation and emission reduction during the "14th five year plan" issued by the State Council clearly stated that the total energy consumption will be liberalized in three ways, and the future energy consumption restrictions of coal chemical industry and building materials industry, which account for a high proportion of energy consumption in the downstream of the coal industry, will also be liberalized, This means that the influence of "dual control of energy consumption" on the demand of the coal industry is gradually weakening. In 2021, under the "double carbon" target of "carbon peak in 2030 and carbon neutralization in 2060", the government will tighten the control of energy consumption more than before. The high energy consumption industry will be more strictly controlled, and the impact of environmental protection and production restriction will be superimposed. The supply of the steel industry will continue to shrink.

4. Conclusions and suggestions

In this paper, SADF and GSADF methods are used to conduct a foam test on China's coal prices from January 2014 to February 2022. The inspection results show that there are many foam in China's coal price during the inspection period, mainly distributed in 2015, the second quarter of 2016, the first and third quarters of 2020 and the first and second quarters of 2021. The longest and most serious price foam occurred from January to September of 2015, lasting for 9 months. The reason is mainly related to the poor price of coal market in recent yearsThe substantial reduction of downstream demand, overcapacity, rapid development of new energy and changes in macro policies. Especially after the "double carbon" target was put forward, the coal price experienced a large increase, the weak demand for coal increased, and the proportion of traditional thermal power decreased under the pressure of

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wind power, hydropower and other new energy sources. Based on this, this paper puts forward the following suggestions:

First, optimize technology and improve the monitoring and early warning mechanism of coal price foam. According to the conclusion of this paper, there are many foam in coal price. Therefore, it is necessary to conduct real-time monitoring on the price of coal as a bulk commodity, establish a special foam detection system for coal price, and prevent and manage it in the early stage of its emergence, so as to shorten the time length of foam generation, So as to reduce the negative impact of foam in coal price.

Second, the government implements steady regulation and control, and can use special bonds to increase investment. As the coal price is greatly affected by the national policies, the government can predict the impact of the policies issued by the government on the coal and carry out certain macro-control so that the coal price can be stable within a certain range, but it fluctuates too much. In addition, the government's measures such as the construction of some major projects and the issuance of special bonds can expand investment, which has a better supporting role for the downstream industry of coal, thus ensuring the stable supply and demand of coal.

Third, strictly control the import and export of coal and stabilize the port inventory. The import and export volume of coal also affects the supply and demand of domestic coal prices, thus affecting the price of coal. Therefore, it is necessary to strictly control the import and export of coal, stabilize the quantity while ensuring the quality, keep it at a relatively average level, and ensure that the port does not press too much inventory, so as to reduce the inventory cost as much as possible.

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