Energy Engineering
DOI: 10.32604/EE.2020.010372

Tech Science Press

Article

Research on the Measurement and Countermeasure of Coal Overcapacity in China: Based on Panel Data of 25 Provinces in China

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Abstract: Coal is the main energy source in China. At present, the coal overcapacity is still serious in China. Accurately measuring the degree of China's coal overcapacity can scientifically resolve the overcapacity, and is the premise of guiding the healthy development of coal industry and energy system. Using the translog cost function and the panel data of coal industry in all provinces of China from 2002 to 2011 and from 2012 to 2016, the research measures and compares the coal production capacity of "golden decade" and "cold winter" in China. The results show that: (1) The change of coal production capacity in China is basically consistent with the development of the economy and the coal industry reformation. The capacity utilization increased year by year in 2002, it was affected by the financial crisis in 2008, and the overcapacity was serious after 2011. (2) At present, the coal overcapacity in each province has been alleviated. We should further strengthen supervision from technology and production structure and other aspects, and continue to complete the work of coal capacity reduction.

Keywords: Coal capacity utilization; panel data; the translog cost function; countermeasure and suggestion

1 Introduction

The consumption of China's coal energy accounted for 59% in 2018. As the main energy in China, the coal energy plays an important role in promoting China's economic and social development. Since 2002, due to the needs of economic development, China's coal industry has got a "golden decade" of rapid development, and the coal production and demand are rising at full speed. However, since 2012, affected by the international economic environment, the decline of domestic economic growth and the situation of energy conservation and environmental protection, the consumption demand of coal in China is declining, supply and demand are unbalanced in the coal market, and overcapacity is gradually emerging. In 2013 and 2016, the State Council of China issued "Opinions on Promoting the Stable Operation of the Coal Industry and Opinions on Solving the Overcapacity of the Coal Industry to Develop by Getting out of Difficulties", which required to eliminate outdated capacity across the country. Therefore, we scientifically measure the degree of overcapacity, which is very important for China and the world to formulate policies and suggestions on capacity reduction.

E. Chamberlin first described the concept of overcapacity. He believed that incomplete competition caused inefficiency of economic organizations, and which led to overcapacity [1]. This view has been recognized by many scholars. However, there are still disputes on how to interpret overcapacity. Only by determining the measurement method of "capacity", we can judge the situation of "overcapacity". However, due to the difficulty of accounting cost and the low availability of data massage, it is difficult to evaluate the degree of overcapacity from the perspective of the concept of overcapacity (Chen et al.) [2]. Therefore, we should not simply start from theoretical perspective, but find a variable that is easy to operate-capacity utilization. By calculating the capacity utilization, we can further judge the degree of overcapacity.

The peak method, frontier method, co-integration method, and peak method are often used to measure the capacity utilization of various industries such as coal industry, steel industry and non-ferrous metals industry. The peak method is a capacity measurement method which take the highest output of an economic agent in a certain period as a metrics (Klein et al.) [3]. Xiong et al. used the peak method to measure the capacity utilization of 26 industries in the manufacturing industry in China from 2003 to 2009, and studied the correlation between capacity utilization and inflation [4]. The function method can be used to measure the capacity utilization, because it defines the "equilibrium state of the enterprise" as a state which the enterprise can produce the highest output under the certain variable costs, fixed costs and production technology (Morrison) [5]. Its measurement form mainly has two kinds: production function and cost function. Yang [6] used the stochastic frontier production function which includes the Sfpanel time-varying inefficiency model to measure the capacity utilization of 36 industries in China from 1999 to 2014. Yang [7] measured the capacity utilization of China's strategic emerging industries in 2010-2014, by using the variable cost function estimation method. The principle of the frontier estimation method is similar to the peak method. It is a measurement method that defines the optimal production frontier as the most efficient output. Yan [8] used the DEA method to estimate industrial capacity utilization in 30 provinces (excluding Tibet) from 2000 to 2015. The capacity utilization can be measured by the cointegration method based on the provation that there is a long-term stable cointegration relationship between capital stock and output (Shaikh et al.) [9]. Ma et al. [10] used the co-integration method to measure the capacity utilization of the steel industry in 30 provinces in China from 2001 to 2012, and calculated the overcapacity of the steel industry in China.

Compared with peak method, frontier method and cointegration method, the function method has a solid micro foundation. Based on a large number of micro data, it calculates the optimal productivity from the perspective of the optimal behavior of enterprises and industries. The cost function method fully considers external factors such as market demand and factor cost. Coal is the main energy source in China, it has high degree of coal marketization, and the coal market is in full competition. The production, sales and price of coal are mainly determined by the market, and it is easy to obtain micro data. Therefore, the cost function method is selected to calculate the capacity utilization rate of China's coal industry. The translog function can provide the approximation of the second order Taylor series in the form of unknown function, provide a flexible functional form that allows alternative elasticity between different parts of the input, have less constraint, and have strong applicability to the production mode with more output and more input. Therefore, this paper constructs the variable cost function of the model in the form of the translog function.

2 Model Construction and Data Description

First, compared with the cross-section data, the panel data has two dimensions that are cross section and time. It greatly increases the sample capacity, helps to correctly analyze the relationship between economic variables, and significantly improves the accuracy of regression. Therefore, this paper uses the panel data of coal mining and washing industry in 25 provinces of China from 2002 to 2016 to measure the capacity utilization. At the same time, in order to find out the difference of capacity utilization between "golden decade" and "cold winter" in coal industry, the data is divided into two stages of 2002-2011 and 2012-2016 for measurement and comparative analysis. Secondly, considering that the data with a time span of more than 5 years is easy to lead to the phenomenon of spurious regression, this paper firstly tests the unit root and cointegration of panel data to determine the stationarity before regression estimation. Based on this, this paper constructs the measurement model of coal overcapacity based on the translog cost function of panel data.

2.1 Model Construction

It is assuming that the production factors of China's coal industry are asset, labor and energy. Its production function can be expressed as follows:

$$Y = F(K, L, E, T) \tag{1}$$

In the formula, Y represents production; K, L and E respectively represent asset, labor and energy; T is total factor productivity and represents technological progress. In the short term, all enterprises in coal industry are constrained by the stock level of fixed production factors, so the capital stock can be considered as fixed factor, and labor and energy are variable factors. In this way, for a given production of Y, under the constraint of fixed capital stock of K, profit maximization can be realized by minimizing variable costs. The variable cost function means that under the given variable factor price and technological level, the coal production by the output of each coal enterprise can minimize the variable cost of coal production. Referring to Lau et al. [11-12], if the labor price and energy price respectively are P_L and P_E, then the function can be expressed as:

$$VC = VC(Y, K, P_L, P_E, T) \tag{2}$$

The variable cost function in the form of the translog function can be approximately expressed as:

$$\begin{aligned}\ln VC = {} & \beta_0 + \beta_Y \ln Y + \beta_K \ln K + \beta_L \ln P_L + \beta_E \ln P_E + \beta_T T \\ & + \frac{1}{2}\beta_{YY}(\ln Y)^2 + \frac{1}{2}\beta_{KK}(\ln K)^2 + \frac{1}{2}\beta_{LL}(\ln P_L)^2 + \frac{1}{2}\beta_{EE}(\ln P_E)^2 \\ & + \frac{1}{2}\beta_{TT}(T)^2 + \beta_{YK}\ln Y \cdot \ln K + \beta_{YL}\ln Y \cdot \ln P_L + \beta_{YE}\ln Y \cdot \ln P_E \\ & + \beta_{YT}\ln Y \cdot T + \beta_{KL}\ln K \cdot \ln P_L + \beta_{KE}\ln K \cdot \ln P_E + \beta_{KT}\ln K \cdot T \\ & + \beta_{LE}\ln P_L \cdot \ln P_E + \beta_{LT}\ln P_L \cdot T + \beta_{ET}\ln P_E \cdot T\end{aligned} \tag{3}$$

In the translog cost function, the coefficient of variable price factor of investment should be primary linear homogeneous, and its parameters should be limited to:

$$\begin{aligned}&\beta_L + \beta_E = 1, \quad \beta_{LL} + \beta_{LE} = 0, \ \beta_{EE} + \beta_{LE} = 0, \\ &\beta_{YL} + \beta_{YE} = 0, \beta_{LT} + \beta_{ET} = 0, \ \beta_{KL} + \beta_{KE} = 0\end{aligned} \tag{4}$$

In order to reflect the optimal behavior of the investment industry, we can add the equation of variable cost share to form the equation group. According to the lemma of Shephard, the conditional input demand of labor and energy can be respectively repressed as $L = \partial VC / \partial P_L$ and $E = \partial VC / \partial P_E$. By using equation (3), we can get the differentiation of $\ln P_L$ and $\ln P_E$, and find that the equation of variable cost share is

$$\frac{L \cdot P_L}{VC} = \frac{\partial \ln VC}{\partial \ln P_L} = \beta_L + \beta_{LE}\ln P_E + \beta_{KL}\ln P_K + \beta_{YL}\ln P_Y + \beta_{LT} \cdot T + \beta_{LL}\ln P_L \tag{5}$$

$$\frac{E \cdot P_E}{VC} = \frac{\partial \ln VC}{\partial \ln P_E} = \beta_E + \beta_{LE}\ln P_L + \beta_{KE}\ln P_K + \beta_{YE}\ln P_Y + \beta_{ET} \cdot T + \beta_{EE}\ln P_E \tag{6}$$

In addition, the short-term total cost (STC) of the enterprise is:

$$STC = VC + FC = VC(P_L, P_E, K, Y, T) + P_K \cdot K \tag{7}$$

In the formula, FC is the fixed cost and P_K is the cost of capital occupation. According to the economic concept of capacity production, the capacity production is from the tangent point of short-term average cost curve and long-term average cost curve. When the short-term average cost curve is tangent to the long-term average cost curve, the short-term marginal cost must be equal to the long-term marginal cost, so there are:

$$SMC = \frac{dTC}{dY}\Big|_{\Delta K=0} = \frac{\partial VC}{\partial Y}$$
$$LMC = \frac{\partial TC}{\partial Y} = \frac{\partial VC}{\partial Y} + \frac{\partial VC}{\partial K}\cdot\frac{dK}{dY} + P_K\cdot\frac{dK}{dY} \tag{8}$$

In the formula, SMC is the short-term marginal total cost, LMC is the long-term marginal total cost, and TC is the total cost. When the short-term average cost curve is tangent to the long-term average cost curve, the short-term marginal cost must be a equal to the long-term marginal cost, that is $SMC = LMC$. So the above formula can be simplified as:

$$\partial VC(P_L, P_E, K, Y^*, T)/\partial K + P_K = 0 \tag{9}$$

The specific results of the capacity production of Y^* is as follows:

Assume：

$$\begin{aligned} Z = \ln VC &= \beta_0 + \beta_Y \ln Y + \beta_K \ln K + \beta_L \ln P_L + \beta_E \ln P_E + \beta_T T + \frac{1}{2}\beta_{YY}(\ln Y)^2 \\ &+ \frac{1}{2}\beta_{KK}(\ln K)^2 + \frac{1}{2}\beta_{LL}(\ln P_L)^2 + \frac{1}{2}\beta_{EE}(\ln P_E)^2 + \frac{1}{2}\beta_{TT}(T)^2 + \beta_{YK}\ln Y\cdot\ln K \\ &+ \beta_{YL}\ln Y\cdot\ln P_L + \beta_{YE}\ln Y\cdot\ln P_E + \beta_{YT}\ln Y\cdot T + \beta_{KL}\ln K\cdot\ln P_L + \beta_{KE}\ln K\cdot\ln P_E \\ &+ \beta_{KT}\ln K\cdot T + \beta_{LE}\ln P_L\cdot\ln P_E + \beta_{LT}\ln P_L\cdot T + \beta_{ET}\ln P_E\cdot T \end{aligned} \tag{10}$$

According to $\ln VC = Z \Rightarrow VC = e^Z$， so

$$\begin{aligned} \frac{dVC}{dK} &= e^Z\left(\frac{\beta_K}{K} + \frac{\beta_{KK}\ln K}{K} + \frac{\beta_{YK}\ln Y}{K} + \frac{\beta_{KL}\ln P_L}{K} + \frac{\beta_{KE}\ln P}{K} + \frac{\beta_{KT}\cdot T}{K}\right) \\ &= \frac{e^Z}{K}(\beta_K + \beta_{YK}\ln Y + \beta_{KK}\ln K + \beta_{KL}\ln P_L + \beta_{KE}\ln P_E + \beta_{KT}\cdot T) \\ &= \frac{VC}{K}(\beta_K + \beta_{YK}\ln Y + \beta_{KK}\ln K + \beta_{KL}\ln P_L + \beta_{KE}\ln P_E + \beta_{KT}\cdot T) \end{aligned} \tag{11}$$

Also because $\frac{dVC}{dK} + P_K = 0$， then:

$$\begin{aligned} &\frac{VC}{K}(\beta_K + \beta_{YK}\ln Y + \beta_{KK}\ln K + \beta_{KL}\ln P_L + \beta_{KE}\ln P_E + \beta_{KT}\cdot T) = -P_K \\ &\beta_K + \beta_{YK}\ln Y + \beta_{KK}\ln K + \beta_{KL}\ln P_L + \beta_{KE}\ln P_E + \beta_{KT}\cdot T = -\frac{P_K\cdot K}{VC} \\ &P_K\cdot K/VC + \beta_K + \beta_{YK}\ln Y + \beta_{KK}\ln K + \beta_{KL}\ln P_L + \beta_{KE}\ln P_E + \beta_{KT}\cdot T = 0 \\ &P_K\cdot K/VC + \beta_K + \beta_{KK}\ln K + \beta_{KL}\ln P_L + \beta_{KE}\ln P_E + \beta_{KT}\cdot T = -\beta_{YK}\ln Y \end{aligned} \tag{12}$$

Further can be obtained

$$\ln Y^* = -\frac{K\cdot P_K/VC + \beta_K + \beta_{KK}\ln K + \beta_{KL}\ln P_L + \beta_{KE}\ln P_E + \beta_{KT}\cdot T}{\beta_{YK}} \tag{13}$$

The capacity production of Y^* is:

$$Y^* = e^{\ln Y^*} \tag{14}$$

If the actual production is Y, then the capacity utilization is equal to the ratio of the actual production to the capacity production, which can be expressed as:

$$CU = \frac{Y}{Y^{*}(P_L, P_E, K, T, P_K)} \tag{15}$$

2.2 Variable Determination and Data Source

According to the availability and scientificness of the data, the model will estimate the capacity utilization of China’s coal industry in 2002-2016 which is based on the concept of capacity production. Firstly, the annual panel data of China' s coal mining industry in 25 major coal producing provinces from 2002 to 2016 are used to estimate the parameters and calculate the capacity utilization.

(1) The capital (K) and the cost of capital occupation (P_K)

At present, there are two main methods to estimate capital stock, one is statistical survey, the other is cost plus. Among them, cost plus has gradually become the mainstream method due to its simplicity. A typical representative is the perpetual inventory method proposed by Godsmi in 1951. Many scholars use this method to estimate the capital stock, this paper also uses this method. The calculation formula is $K_t = K_{t-1}(1-\delta) + I_t$, K_t and K_{t-1} are respectively the capital stock of the t year and the $t-1$ year, billion; δ is the depreciation rate. According to the character of coal industry, 7% is selected. I_t is the actual fixed asset investment in t years, and the index of fixed asset investment price is used to deflate. The capital stock in the base year refers to the calculation method of Li [13], which is the ratio of the sum of the fixed asset investment amount and the annual increase rate and depreciation rate of the fixed asset investment amount in the base year. The price index of fixed asset investment comes from Statistical yearbook of china, and the total fixed asset investment data of coal mining and washing industry comes from China Energy Statistical Yearbook.

The calculation method of the cost of capital occupation refers to the calculation method of Zhao [14]. Assuming the purchase price of capital is p , the enterprise has a unit of capital will produce three costs. The first is the interest income that will be obtained from the sale of capital and saving which is $r \cdot p$, and r is the actual interest rate; Second, capital loss caused by capital depreciation which is $\delta \cdot p$; the third is the cost caused by the change of capital price which is $p'p$, and p' is the price change rate. The user cost of the company’s own capital can be obtained by summing up the costs in the above three aspects which is $P_K = (r + \delta + p')p$. This article selects the difference between the three-year statutory deposit interest rate of the financial institution and the three-year average inflation rate as an indicator of the actual interest rate, the capital price is replaced by the fixed asset investment price index, which is flattened to the price in 2002. The data comes from China Statistical Yearbook.

(2) The energy input (E) and the price of energy input (P_E)

The energy input is the total energy consumption of the coal mining industry over the years. The data comes from the annual China Energy Statistical Yearbook and the Statistical Yearbooks of provinces. Because the unit of total energy consumption is 10,000 tons of standard coal, the energy prices are replaced by the “purchased price index of industrial producers of fuel and power” for each year.

(3) The labor input (L) and the price of labor input (P_L)

The labor input is replaced by the number of all employees in coal mining industry at the end of the year. The labor price is based on the average wage of employees, which is deflated to the 2002 price by the “residential consumer price index”. The data comes from the Yearbook of labor statistics.

(4) Output (Y)

The output is replaced by the provincial raw coal output. The data comes from the Statistical Yearbook of each province.

(5) Technological progress (T)

According to the methods widely adopted in most literatures and the setting of measurement models, the time trend term T is chosen to represent spontaneous technological progress.

3 The Inspection of Panel Cointegration

Considering the limitations of the model and the availability of data, this paper uses the panel data of 25 provinces in China from 2002 to 2016 for regression estimation. First, the data are descriptive statistics. Secondly, in order to prevent the occurrence of spurious regression problem, generally, the stationarity of panel data models with the time greater than 5 should be verified firstly.

3.1 Unit Root Test

Eviews 8.0 software is used to test the unit root of each variable. LLC test, IPS test, ADF test, and PP test are used. The unit root test results are shown in Tab. 1, which meet the cointegration test condition.

Table 1: Unit Root Test Results

Test	LLC	IPS	ADF	PP
Y	-8.1302***	-4.5707***	108.662***	119.513***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
K	-21.5107***	-18.1789***	228.246***	273.494***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
PK	-25.6796***	-18.5487***	328.568***	332.517***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
L	-4.5618***	-1.5746*	74.2081**	81.5586***
	(0.0000)	(0.0576)	(0.0147)	(0.0032)
PL	-12.83***	-6.4671***	127.378***	160.965***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
E	-4.4200***	-1.3842*	70.5696**	71.7163**
	(0.0000)	(0.0831)	(0.0292)	(0.0237)
PE	-11.3111***	-6.0573***	115.437***	133.154***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: p values are in brackets; *, ** and *** are significant at 10%, 5% and 1% levels respectively.

The test results show that the sequence of $\ln Y$, $\ln K$, $\ln P_K$, $\ln P_L$ and $\ln P_E$ is significant at 5% level, the sequence of $\ln L$ and $\ln E$ is significant at 10% level. All variables are horizontally stable and meet the cointegration test condition.

3.2 Panel Data Cointegration Test

According to the measurement principle for panel models, if the variables are not stable, it is necessary to test the cointegration relationship between the variables before performing regression analysis to avoid the problem of spurious regression of panel data. Therefore, it is necessary to test the cointegration of variables. In order to ensure the reliability and robustness of the results, Pederoni test and Kao Test are used to determine whether there is a long-tern equilibrium relationship between the variables. The original hypothesis of Pedroni test and Kao test is that there is no cointegration relationship, and the lag order is determined by SIC criterion. Using Eviews8.0, the test results are as follows:

Table 2: Panel Data Cointegration Test Results

Test		Statistical test	P
Pedroni test	Panel e-statistic	-3.7196	0.9999
	Panel rho-statistic	5.6371	1.0000
	Panel PP-statistic	-1.9861	0.0235
	Panel ADF-statistic	-5.9089	0.0000
	Group rho-statistic	7.0830	1.0000
	Group PP-statistic	-4.9293	0.0000
	Group ADF-statistic	-3.6741	0.0001
Kao test	ADF	-2.9561	0.0016

According to the test results in Tab. 2, except for the three statistics of Panel e, Panel rho, and Group rho are not significant, the remaining five statistics reject the original hypothesis that there is no cointegration relationship at the significant level of 1% or 5%. Therefore, there is cointegration relationship between the data, and regression analysis can be conducted directly.

4 The Measurement of Coal Capacity Utilization Based on Panel Data

According to the method of overcapacity measurement in this paper, under the restriction of Eq. (4), the panel data which has passed the cointegration test is substituted into the equation group composed of Eq. (3), Eqs. (5) and (6) to obtain the estimated value of parameters. In order to find out the difference of development between the "golden decade" of the coal industry and the years of severe overcapacity in China's coal industry, this paper divides the data into two phases of 2002-2011 and 2012-2016 to carry out regression and capacity utilization calculation. In order to ensure that the covariance matrix of the error term of the system of equations is nonsingular, the energy share equation is removed. The estimation method used in this paper is similar uncorrelated regression (SUR).

4.1 Measurement Results of Coal Overcapacity in Each Province from 2002 to 2011

4.1.1 Parameter Estimation

The parameter estimation results from 2002 to 2011 are shown in Tab. 3. The regression results of the data are good, and the goodness of fit is 0.90, and the parameters are significant.

Table 3: Regression results from 2002 to 2011

Parameter	Regression results	Parameter	Regression results
β_0	7.9778** (2.1074)	β_{YK}	-0.1370*** (0.0960)
β_Y	0.1716** (0.6756)	β_{YL}	-0.0001** (0.0049)
β_K	1.0554** (0. 5943)	β_{YE}	0.0001** (0.0049)
β_L	0.9002** (0.1865)	β_{YT}	-0.0052** (0.0023)
β_E	0.0998** (0.1865)	β_{KL}	-0.0002*** (0.0042)
β_T	-0.3751*** (0.0769)	β_{KE}	0.0002*** (0.0042)
β_{YY}	0.0438** (0.0575)	β_{KT}	-0.0107** (0.0196)
β_{KK}	0.0882*** (0.0390)	β_{LE}	-0.0013* (0.0095)

β_{LL}	0.0013* (0.0095)	β_{LT}	0.0001* (0.0016)
β_{EE}	0.0013* (0.0095)	β_{ET}	-0.0001* (0.0016)
β_{TT}	0.0453* (0.0185)	R^2=0.90 P=0.000	

4.1.2 Capacity Measurement Results

Table 4: Measurement results of overcapacity in each province from 2002 to 2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Beijing	67.85%	73.37%	87.80%	90.00%	84.09%	84.63%	67.39%	61.38%	65.37%	72.63%
Hebei	71.24%	74.02%	92.40%	89.11%	83.29%	82.77%	74.51%	74.52%	86.12%	85.87%
Guangxi	62.69%	64.44%	75.36%	88.86%	83.65%	85.38%	71.23%	77.11%	80.28%	80.56%
Chongqing	74.91%	71.14%	86.55%	88.66%	88.92%	85.16%	69.40%	68.26%	70.30%	83.26%
Sichuan	63.75%	75.12%	83.44%	88.37%	85.06%	87.81%	70.77%	80.18%	76.79%	82.27%
Guizhou	71.55%	73.18%	84.08%	86.16%	93.30%	84.85%	72.41%	81.56%	88.57%	80.13%
Yunnan	70.98%	87.82%	89.86%	96.46%	99.04%	85.77%	72.95%	70.87%	76.35%	78.80%
Shanxi	67.17%	70.44%	84.47%	90.48%	92.26%	88.64%	80.94%	93.52%	96.91%	93.96%
Gansu	61.58%	62.24%	81.91%	90.98%	85.23%	82.30%	80.85%	75.61%	88.66%	86.11%
Qinghai	66.53%	71.58%	91.52%	97.09%	88.82%	83.32%	75.08%	78.04%	88.67%	82.45%
Ningxia	77.41%	80.17%	89.18%	73.16%	76.56%	72.69%	72.20%	80.08%	88.17%	85.27%
Hunan	67.89%	74.60%	88.43%	89.18%	90.53%	83.30%	73.72%	70.24%	76.17%	84.43%
Hubei	69.87%	85.41%	93.06%	94.03%	86.31%	78.49%	72.16%	65.78%	74.62%	70.65%
Henan	64.21%	71.55%	95.25%	96.26%	92.10%	83.89%	72.73%	76.40%	82.47%	76.32%
Xinjiang	68.08%	72.76%	98.09%	92.74%	87.83%	80.69%	75.21%	79.97%	86.15%	90.76%
Shanxi	65.74%	70.70%	84.24%	91.24%	92.59%	88.94%	81.36%	76.71%	73.31%	76.41%
Neimenggu	67.36%	72.74%	93.53%	94.37%	84.00%	88.83%	69.32%	70.73%	81.88%	91.40%
Liaoning	71.13%	78.64%	91.31%	82.28%	92.42%	78.31%	77.67%	77.90%	79.87%	72.50%
Jilin	70.30%	78.38%	98.81%	85.35%	80.21%	72.31%	66.58%	70.81%	85.55%	88.05%
Heilongjiang	54.63%	60.42%	81.68%	84.07%	88.02%	86.22%	80.64%	68.49%	72.16%	76.10%
Jiangsu	69.26%	77.80%	80.47%	84.61%	93.91%	87.80%	70.95%	72.85%	78.33%	79.36%
Anhui	65.97%	77.23%	86.55%	82.20%	87.66%	90.03%	73.53%	75.07%	87.54%	87.21%
Fujian	69.02%	79.20%	94.45%	96.53%	99.02%	84.19%	68.12%	71.33%	74.08%	83.32%
Jiangxi	56.12%	66.06%	99.41%	98.41%	88.83%	82.78%	69.15%	72.78%	75.29%	80.03%
Shandong	74.19%	92.04%	89.85%	83.25%	81.03%	81.06%	74.38%	75.51%	79.75%	79.59%

4.2 Measurement Results of Coal Overcapacity in Each Province from 2012 to 2016

4.2.1 Parameter Estimation

The parameter estimation results from 2012 to 2016 are shown in Tab. 5. The regression results of the data are good, and the goodness of fit is 0.94, and the parameters are significant.

Table 5: Regression results for 2012-2016

Parameter	regression results	Parameter	regression results
β_0	6.2210*** (5.9737)	β_{YK}	0.4882* (0.4348)
β_Y	6.6980** (1.8061)	β_{YL}	-0.0001** (0.0109)
β_K	0.3862** (2.8668)	β_{YE}	0.0001** (0.0109)
β_L	1.3575** (0.5016)	β_{YT}	-0.0049** (0.0045)
β_E	-0.3575** (0.5016)	β_{KL}	-0.0004*** (0.0120)
β_T	-1.2355** (0.9625)	β_{KE}	0.0004*** (0.0120)
β_{YY}	-0.9640* (0.2157)	β_{KT}	0.0810** (0.1277)
β_{KK}	-0.7114** (0.2046)	β_{LE}	0.0016* (0.0259)
β_{LL}	-0.0016* (0.0260)	β_{LT}	1.27e-16* (2.92e-17)
β_{EE}	-0.0016* (0.0260)	β_{ET}	-1.27e-16* (2.92e-17)
β_{TT}	0.0596* (0.0419)	R^2=0.94 P=0.000	

4.2.2 Capacity Measurement Results

Table 6: Results of overcapacity measurement in each province from 2012-2016

	2012	2013	2014	2015	2016
Beijing	43.90%	44.55%	63.27%	77.91%	68.89%
Hebei	78.09%	67.97%	63.15%	74.14%	77.13%
Guangxi	58.45%	60.26%	60.17%	47.64%	56.70%
Chongqing	61.21%	68.60%	52.53%	71.62%	70.00%
Sichuan	67.54%	54.11%	73.92%	73.24%	75.21%
Guizhou	64.82%	71.11%	75.90%	76.75%	78.09%
Yunnan	76.75%	70.77%	65.53%	79.27%	82.72%
Shanxi	73.69%	75.56%	67.79%	76.19%	77.96%
Gansu	64.03%	60.28%	68.18%	69.49%	76.04%
Qinghai	69.57%	74.49%	77.62%	75.30%	79.42%
Ningxia	72.99%	64.56%	55.10%	62.49%	70.75%
Hunan	62.27%	66.63%	69.51%	62.19%	68.80%
Hubei	64.60%	66.74%	64.30%	80.30%	83.39%
Henan	69.47%	70.00%	69.44%	73.04%	72.11%
Xinjiang	76.71%	73.87%	70.07%	76.42%	78.23%
Shanxi	71.62%	73.60%	66.57%	77.99%	75.56%
Neimenggu	72.64%	71.37%	75.11%	75.02%	76.63%
Liaoning	75.85%	71.20%	69.12%	74.00%	74.38%

Jilin	83.41%	51.98%	69.27%	77.04%	73.84%
Heilongjiang	64.68%	60.24%	59.14%	61.08%	61.48%
Jiangsu	68.87%	68.16%	62.46%	77.26%	80.20%
Anhui	65.55%	66.53%	67.95%	79.15%	81.77%
Fujian	76.27%	78.84%	67.83%	74.92%	77.72%
Jiangxi	62.25%	62.24%	47.32%	67.75%	69.28%
Shandong	69.45%	65.34%	70.78%	75.65%	75.17%

It can be seen from Tab. 4 and Tab. 6:

(1) The change of coal capacity utilization in most regions is basically consistent with the change of economy development and the reform of coal industry in China. Before 2002, with the implementation of the reform and opening up policy, the development of various industries became more active. In order to meet the energy demand of economic development, the state has taken many measures to increase coal production. For example, the general contracting system based on "Three Guarantees" was implemented for large state-owned coal mining enterprises, and local coal mines and small mines actively developed, and the policy of "development simultaneously of large, medium and small coal mines" was advocated. Under the guidance of these management policy, the small coal mines have developed rapidly in China, but the quality is quite low, and excessive development has brought a lot of waste of resources. After 2002, the coal industry entered a period of consolidation. The policies were promulgated which included liberalizing the operation rights of large state-owned coal mines, closing small coal mines, and reducing coal production. The coal economy gradually went out of the trough, and the capacity utilization of coal industry also showed an upward trend. During the "golden decade" of the coal industry from 2002 to 2011, the coal production of each province was in good condition, the demand continued to rise, and fewer provinces experienced overcapacity. Among them, from 2005 to 2007, the coal production capacity has been well developed, and the capacity utilization has reached the highest point. After 2008, affected by the financial crisis, in order to stimulate the economy, the Chinese government launched the "four trillion" rescue plan. The huge demand and the "surge phenomenon" of the investment subjects have jointly caused the rapid growth of the fixed asset investment in the coal industry, and at the same time also led to the irrational expansion of the coal industry. With the slowdown of domestic economic growth, the demand for coal suddenly declined after the rapid growth. But the capacity formed by a large amount of investment in the early stage had not been released, which led to the decline of capacity utilization of coal industry, and the problem of overcapacity is increasingly prominent. From 2008 to 2009, the coal capacity utilization in each province declined, and overcapacity occurred in most regions. It recovered slightly from 2010 to 2011. During the "cold winter" period of 2012-2016 of coal industry, the demand of coal in each province decreased, the price of coal decreased, and the output continued to rise at the initial stage. There was a nationwide overcapacity phenomenon, and most provinces had severe overcapacity. After 2016, at the call of the central government, the local governments successively introduced "capacity reduction" policy, which eased the phenomenon of overcapacity.

(2) By observing the industrial capacity utilization in the United States, it can be seen that the capacity utilization may occasionally exceed 100%. According to the Federal Reserve data, the average capacity utilization rate of the United States from 1972 to 2013 was 80.1%; according to its experience, 79% to 83% of capacity utilization is within a reasonable range, less than 79% is excess, and more than 83% is capacity insufficient [15]. According to the above standards, the provinces in China which the current production capacity is recovering in good condition are Guizhou, Yunnan, Shanxi, Qinghai, Hubei, Xinjiang, Jiangsu, and Anhui. The provinces with severe overcapacity are Beijing, Guangxi, Heilongjiang, Jiangxi, Hunan, and Chongqing. The work of coal capacity reduction in China has begun to bear fruit. We should further start from technology and production structure to continue, and complete the coal capacity reduction work.

5 Conclusions and Policy Implication

Resolving coal overcapacity is a major challenge for China's energy science development. In this paper, we use the translog cost function to measure and compare the capacity utilization of coal industry in 25 provinces of China in different periods from 2002 to 2011 and from 2012 to 2016. It is concluded that (1) the changes in the coal capacity utilization in most regions are basically consistent with the changes in China's economy development and the reform of the coal industry. During the "Golden Decade", the capacity utilization of each province has been continuously improved since 2002, it has started to decline in 2008, and has picked up slightly in 2010. However, with the arrival of the "cold winter" in the coal industry, there is a serious overcapacity. (2) Under the careful decision research, formulation and adjustment of the Chinese government, many local governments have made positive response to the capacity reduction policy. The coal capacity reduction policy has achieved good results at this stage in China. At the same time, according to the above measurement results of the degree of overcapacity in each province, it can be seen that the overcapacity in most provinces has eased after 2016.

Therefore, this study analyzes the current status of China's coal capacity reduction and puts forward relevant suggestions:

(1) It is a long-term work to eliminate outdated capacity.

In 2016, the Central Government successively issued the opinions on dissolving overcapacity in the coal industry to realize the development of getting rid of difficulties and the opinions on dissolving overcapacity in the iron and steel industry to realize the development of getting rid of difficulties. The two industries with severe overcapacity in coal and steel were identified as the key areas for capacity reduction. It is clearly stated in the document that the capacity reduction plan of coal industry is to start from 2016, and take 3 to 5 years to withdraw about 500 million tons of capacity, reduce and reorganize about 500 million tons. By the end of 2018, the entire industry had withdrawn from coal production capacity of more than 800 million tons, and basically completed the "13th Five-Year Plan" of coal capacity reduction in China. In addition, a number of large modern coal mines have been newly approved and constructed, and the proportion of high-quality production capacity has increased significantly. The performance of capacity reduction need change from total volume control to structural capacity reduction and superior production capacity.

From the perspective of demand, on the one hand, the long-term development trend of China's economic stability to good and steady progress has not changed. The economic growth is shifting to high-quality development, which will further drive energy demand, and the proportion of electricity in terminal energy consumption is increasing. The higher the demand for electric coal is expected to increase. On the other hand, the uncertain factors of economic development at home and abroad are increasing. At the same time, with technological progress, national governance of the atmospheric environment, energy conservation and emission reduction, the non fossil energy is increasingly replacing coal, and the coal consumption growth will decrease. However, the coal supply is still growing in China. In 2018, China's raw coal output was 3.68 billion tons, up 4.5% year on year. The import of raw coal increased. In 2018, China's coal import reached 281 million tons, up 3.9% year on year; the export reached 4.934 million tons, down 39% year on year; the net import reached 276 million tons, up 5.2% year on year.

In summary, the current coal production capacity in China is still relatively high, and structural problems are still outstanding, and the overall overcapacity will become the normal in the next period. Factors such as technological progress, increased investment, and large-scale coal mine output will promote the continuous release of new coal production capacity, further increase in coal production, and make it more difficult for the government to regulate the coal market. The coal output will further increase, and the government's adjustment of the coal market will become more difficult. Therefore, the capacity reduction of coal industry is a continuous process, and structural capacity reduction after 2019 is also the focus of coal capacity reduction in the future.

(2) Pay attention to the implementation of the capacity reduction policy.

After September 2016, the outdated capacity seceded, the coal demand increased, and the coal industry had overall recovery. In 2018, benefiting from the continuous promotion of supply-side reform and capacity reduction, downstream demand improved better than expected, the overall supply and demand of coal industry continued to be tight, the coal price was running at a high level throughout the year, and the industry profits also picked up. Except for Pingzhuang Energy, 28 large coal mining enterprises had all achieved profits, and their net profit was 89.7 billion yuan in 18 years, up 3.9% year on year. At the same time, from the consideration of local development and social development, the local governments were unwilling to close the mines with outdated capacity, they ignored the policy of capacity reduction which was issued by the central government. The implementation was not in place, and even the production capacity was guaranteed in secret. On the other hand, some coal enterprises did not adjust their business plans in time. While in response to the policy of capacity reduction, the reduction in coal production capacity made the operation of the enterprise itself under pressure and impact. As a result, the operating conditions of enterprises had deteriorated, losses had occurred, and even some related industries had also caused chain operation problems. Therefore, attention should be paid to the implementation of capacity reduction policy in various places and enterprises to ensure the smooth completion of capacity reduction task.

(3) Strengthen structural capacity reduction

The elimination of outdated capacity and the release of high-quality production capacity in the coal industry should not only consider the scale of production capacity, but also comprehensively consider whether the enterprise is a zombie enterprise and the produce technical level of the coal mine. Such as the level of safety production and environmental protection, as well as the supply and demand of the coal market in the region. In addition, in order to effectively remove some inferior and inefficient coal mines, the whole industry should pay more attention to technological progress and the improvement of the coal technology innovation system. In order to solve the problems of basic theoretical research and key technologies such as resource development, major disaster prevention, clean utilization, and efficient transformation, it is necessary to introduce advanced production technology, purchase large-scale and efficient mining equipment, explore mineral resources, and establish large-scale and powerful coal mining enterprises. At the same time, in terms of promoting the integration of upstream and downstream coal related industries, we should vigorously promote the integration of coal, electricity, chemical industry and so on. Finally, the production and resource structure of whole industry will be improved, and the industrial concentration will be further improved.

Acknowledgement: The authors sincerely thank the assistance of Zhang Qianqian and Chang Xinyan for establishing the model and collecting the data.

Funding Statement: The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was jointly funded by the “13th Five-Year Plan” National Key R&D Program (Grant Nos. 2016YFC0801906), Yangquan Coal Industry (Group) Co., Ltd. Research Project (Grant Nos. 2017008326) and the Yueqi Outstanding Scholar Project.

Conflicts of Interest: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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