[*THE IMPACT OF GLOBAL OIL PRICE FLUCTUATION ON THE DEVELOPMENT BENEFIT OF CBM IN SHANXI，CHINA*]

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Abstract

Soaring demand for clean energy and more stringent environmental policies encourage China's largest coal producing province, Shanxi, to develop coal-bed methane（CBM） to serve the local markets. However, most of the CBM fields in Shanxi have poor permeability and gas content. The local CBM development is going through the period of a low single well output and a long investment recovery. Therefore, its ability to cope with fluctuation in global oil prices is also relatively poor.

Although global oil price volatility cannot directly impact the benefits of CBM development, its recent fluctuations have had a certain impact on the investment costs and benefits of local CBM development in Shanxi. This paper analyzes the impact of global oil price volatility on the input and output factors of CBM development, so as to sort out the conduction path of oil price impact on development benefits. By selecting various statistical indicators, and using trend analysis, correlation analysis and regression analysis to quantify the impact of oil price on CBM development input and output; We select the Net Present Value（NPV） as the benefit indicator, analyze the sensitivity of the NPV to each affected input and output factor, and quantify the importance of the affected factor to the development benefit. In the end, the interesting result shows for every 1% increase in the global oil price, the CBM development revenue decreases by 2.818%. The analysis shows that the main reason is the Chinese government's control over CBM prices.

Introduction

Since June 2014, the continuous fluctuation of global oil price has had a huge impact on the development and utilization of unconventional oil and gas such as CBM in China. The poor development benefits have made national and private capital unwilling to invest in the production and R&D of CBM in China. China's CBM 12th Five-Year Plan has a production target of 30 billion cubic meters per year, and the actual production in 2016 is only 4.425 billion cubic meters. Due to the sluggish global oil price, in March 2016, the Ministry of Finance of China determined that the subsidy for pure CBM will increase from 0.2 CNY to 0.3 CNY per cubic meter during the 13th Five-Year Plan period. The CBM production has reached 7.26 billion cubic meters in 2018, which is expected to reach the target of the 13th Five-Year Plan (the production target of CBM in 2020 is 10 billion cubic meters).

China's proven reserves of coal in Shanxi Province is 3.01×10^{11} tons, accounting for about 20% of China's total reserves; CBM resources are 1.04×10^{13} m^3, accounting for more than 30% of China. In 2018, Shanxi's CBM production was 5.12 billion square meters, accounting for more than 70% of China's total CBM production, accounting for 53% of Shanxi's total natural gas consumption. CBM is an important and special clean energy source in Shanxi, but its resource quality is not outstanding. Compared with the US Powder River Basin, most of the CBM fields in Shanxi have low permeability and poor gas content. Therefore, the local CBM development has a low single well output and investment recovery. The investment payback period is long, so its ability to cope with fluctuation of global oil price is also relatively low.

From the perspective of technical and economic evaluation, this paper selects NPV as the evaluation index of the life cycle benefit of CBM development, and Quantifies the impact of oil price on development benefit evaluation parameters such as local CBM price, market size, investment and related operating costs in Shanxi. Combining with the sensitivity analysis of NPV to various investment costs, this article studies the transmission of oil price fluctuations to Shanxi local CBM development benefits, and analyzes its ability to resist global oil price fluctuations.

1. The impact mechanism of global oil price fluctuation on the development benefit of CBM in Shanxi

In the past, the research on the impact of global oil price fluctuation on the development benefit of CBM was mostly qualitative research. And it was not based on the technical economic evaluation parameters, In this paper the mechanism of the impact of oil price fluctuation on the development benefit of CBM will be sorted out to quantify the degree of impact.

1.1 Technical evaluation model of CBM development benefits

The discounted cash flow method, also known as the NPV method, examines the profitability of projects throughout the life cycle, can effectively reflect the project development benefits, and reflects the characteristics of the company's pursuit of maximizing economic benefits (DK Luo,2015). In the evaluation of CBM development, It's the most effective and feasible method, and widely accepted by domestic and foreign companies. NPV is the difference between the discounted cash inflows and the cash outflows during the life of the project. The formula is:

$$NPV = \sum_{t=1}^{n} (CI - CO)_t (1+i)^{-t} \quad (1)$$

Where: NPV is the Net present value of the project, 1×10^4 CNY; CI is cash inflow, 1×10^4 CNY; CO is cash outflow, 1×10^4 CNY; i is the benchmark discount rate; t is the year number; n is the project period, year.

For CBM exploration and development projects, the main cash inflows during the life cycle include CBM sales revenue, subsidy income and Tax rebates. The main cash outflows include exploration investment, drilling engineering investment, fracturing engineering investment, and ground engineering. Construction investment, operating costs, working capital and taxes. Therefore, the technical and economic evaluation model of CBM development benefits in the whole life cycle is:

$$NPV = R_s + R_b + R_t - I_k - I_z - I_y - I_d - C_t - C_j - C_l - C_i - T_x$$

Where: R_s is sales income, 1×10^4 CNY; R_b is subsidy income, 1×10^4 CNY; R_t is after-sales tax rebate income, 1×10^4 CNY; I_k is exploration investment, 1×10^4 CNY; I_z is drilling engineering investment, 1×10^4 CNY; I_y is fracturing engineering investment, 1×10^4 CNY; I_d is investment in ground engineering construction, 1×10^4 CNY; C_t is compensation for land resources, 1×10^4 CNY; C_j is operating cost, 1×10^4 CNY; C_l is loss of working capital, 1×10^4 CNY; C_i is bank loans expense, 1×10^4 CNY; T_x is the tax, 1×10^4 CNY; all of the above are discounted values.

1.2 Transmission mechanism of global oil price impact on CBM development benefits

The impact of oil price on CBM development is reflected in the impact of oil price fluctuation on local gas prices (there is no difference between CBM prices and natural gas prices in Shanxi Province), and the impact on national and local subsidy policies (China's governments at all levels have subsidy policies for CBM development) and the impact of price level of fuel power and chemical raw materials in the development process. It is therefore necessary to analyze the conduction mechanism of this effect, to clarify the conduction path of this effect, and to calculate the actual size of this effect.

In terms of cash inflows, changes in global oil price will cause changes in global natural gas prices (AK Tiwari,2019), which in turn will cause domestic CBM price changes; it will also affect the market size of natural gas; long-term high oil prices or low oil prices will further affect National subsidy policy for unconventional natural gas such as CBM (DK Luo,2009 ; JH Yuan,2015).

In terms of cash outflows, different investment costs are affected by oil prices to varying degrees (DHB Phan,2019). The fuel power and transportation related costs in the development of CBM are directly affected by

changes in oil prices; The fluctuation of oil price is transmitted to the price level, which indirectly influences the compensation of land resources, relevant exploration and development investment, sales expenses, management expenses and other operating costs through inflation, human resource costs and other factors (LH Zhu,2016; JH Yuan,2015). The specific conduction path is shown in Figure 1 below:

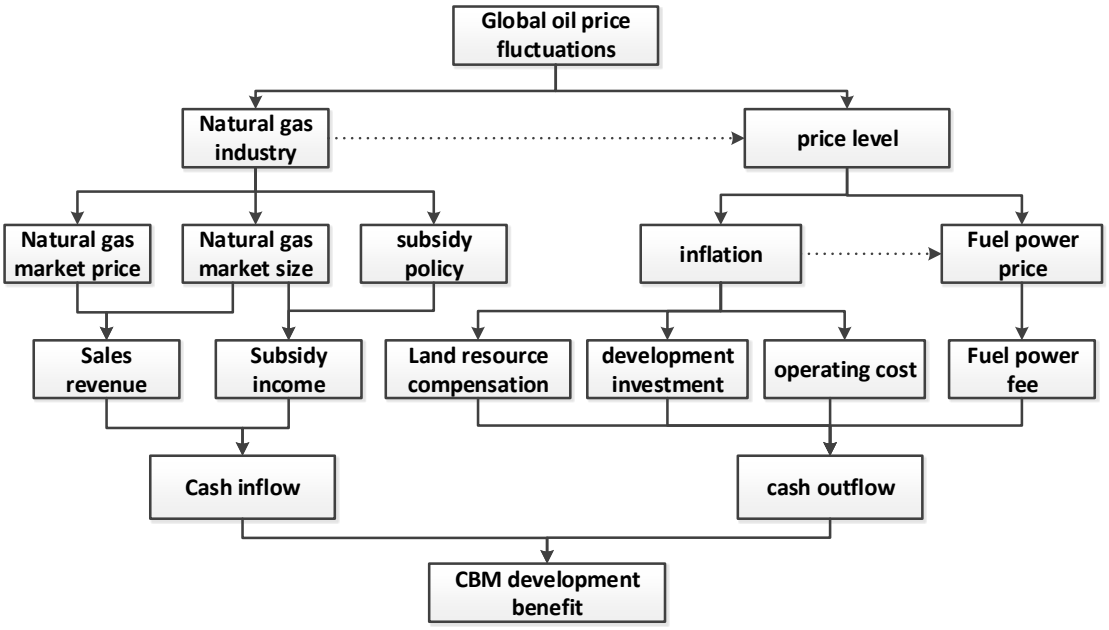

Figure 1 Transmission mechanism path of the impact of global oil price fluctuation on CBM development benefits

2. Quantification of the impact of global oil price fluctuations on the evaluation parameters of Shanxi CBM development benefits

To quantify the impact of oil price fluctuation on the evaluation parameters of CBM development benefits, on the one hand, the detailed data of CBM development benefit evaluation parameters over the years has been difficult to obtain, and the evaluation parameters of each development block are not the same; on the other hand, China's CBM development time is relatively short. Effective time series analysis and regression analysis are not possible. Therefore, various statistical indexes are selected as the basis for reflecting the fluctuation of evaluation parameters, and the regression coefficient of oil price and statistical index is calculated to quantify the impact of oil price.

2.1 Selection of evaluation parameter indicators affected by oil price

The fluctuation of oil price will affect the following factors in the development of CBM in Shanxi: CBM price, local market size of CBM, CBM subsidy policy, land resource compensation fee, exploration and development investment, and fuel power cost, operation cost, management Operating costs such as service fees.

This article selects the ex-factory price index of oil and natural gas mining industry to measure the change of China's CBM price, GPPI for short; selects the total amount of natural gas consumption chain index as a measure of market size change, GCI for short; selects fixed asset investment price index to reflect the index of changes in land resource compensation fees and exploration and development investment , IPI for short; the industrial producer purchase price index (fuel power) is selected as the fuel power fee change index for CBM development, FPI for short. For the running cost part of operating costs, Wang(2016) Used EIA (Energy Information Administration) data for first-order differential regression, it is considered that 1% change in oil price leads to a change of running cost of oil and gas mining industry by 0.18%,this conclusion is adopted in this paper. For other operating costs, such as management expenses, sales expenses, workers Salary, etc., this article selects the consumer price index as a reflection index of other CBM operating costs , CPI for short; selects Brent annual average oil price, Dubai annual average oil price, WTI average oil price as global oil prices, calculate the mean

chain index of the 3 global oil prices as the index to reflect the oil price fluctuation, OPI for short. It is Assumed that the CBM subsidy policy will remain stable in the short term.

Due to the statistical caliber and data reasons, the data from 2006 to 2017 for 12 years were selected as the research object to study the impact of oil price fluctuation on the changes of various development benefit evaluation parameters of CBM development. The crude oil price comes from "World Bank Annual Price Data 2019.01", and other price indices are from "Shanxi Statistical Yearbook" (2007-2018) and "China Energy Statistical Yearbook" (2007-2017). The specific data are shown in table 1 as follows.

Table 1 Changes in global oil price and evaluation indicators of CBM development benefits in Shanxi Province from 2006 to 2017

(last year=100)

Year	Three global oil price averages ($/bbl)	Oil price chain index	Oil and gas mining industry ex-factory price index	Natural gas consumption chain index	Fixed asset investment price index	Industrial producers purchase price index (fuel power)	Consumer Price Index
Shortening	OP	OPI	GPPI	GCI	IPI	FPI	CPI
2006	64.29	120.41	100	115.49	101.5	104.5	102.0
2007	71.12	110.62	100	100.94	104.1	105.3	104.6
2008	96.99	136.38	100	99.18	113.3	123.2	107.2
2009	61.76	63.67	100.7	95.40	98.1	101.8	99.6
2010	79.04	127.99	100.3	114.74	103.7	104.9	103.0
2011	104.01	131.59	106.5	111.05	105.5	106.2	105.2
2012	105.01	100.96	100.3	100.08	101.2	98.2	102.5
2013	104.08	99.11	100.9	110.13	100.5	94.7	103.1
2014	96.24	92.46	103.8	126.95	99.6	94.3	101.7
2015	50.75	52.74	99.4	100.38	98.2	93.2	100.6
2016	42.81	84.35	90.7	100.35	100	100.5	101.1
2017	52.81	123.34	110.3	110.25	106.3	119.8	101.1

2.2 Indicator change trend and correlation analysis

According to Table 1, the change curve of the evaluation parameters of the global oil price and the oil price is plotted as Figure 2. The trend of each indicator is analyzed.

It can be found from Figure 2 above that except for the natural gas market size indicator GCI and the natural gas price index GPPI, the fluctuation of other evaluation indexes are basically the same as OPI, but the fluctuation range is not the same. Therefore, in order to quantify the extent of the impact of oil prices on various evaluation parameters, further correlation analysis is needed.

Correlation analysis generally selects correlation coefficient to measure the degree of correlation between factors. The linear correlation coefficient is a statistical index reflecting the correlation between variables (LS Zhai,2019), and its calculation formula is shown in the following formula 3:

$$r(X,Y)=\frac{Cov(X,Y)}{\sqrt{Var[X]Var[Y]}} \quad (3)$$

Where X, Y are the variable sequences, Cov(X, Y) is the covariance of X and Y, Var[X] is the variance of X, and Var[Y] is the variance of Y.

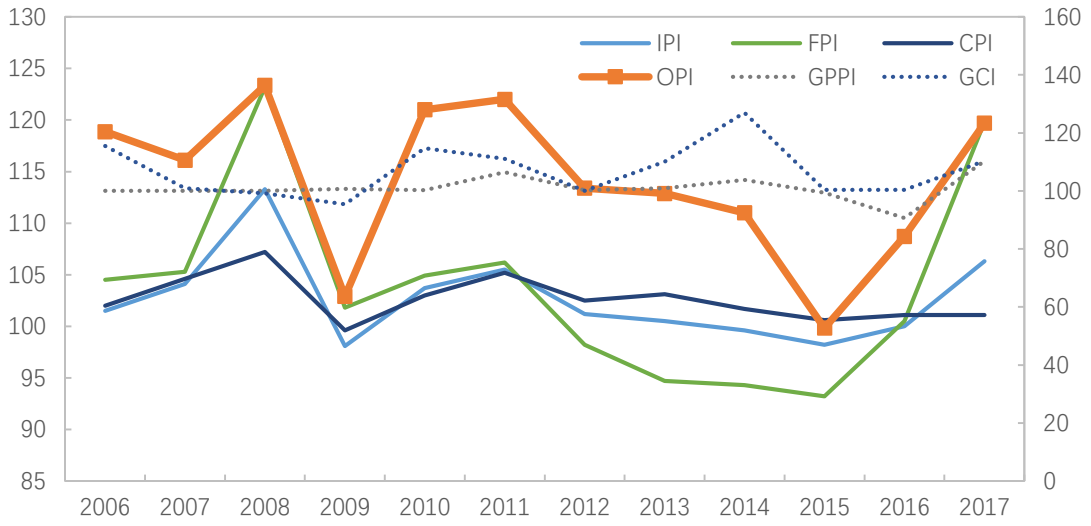

Figure 2 Oil price index OPI and the trend of evaluation parameters affected by it

After calculation, the correlation coefficient between the oil price index and other change indexes is shown in Table 2 below:

Table 2 Linear correlation coefficient between global oil price and various expenditure indexs of Shanxi CBM development

Index	GPPI	GCI	IPI	FPI	CPI
OPI	0.385	0.339	0.810	0.691	0.736
Relevance	Medium	Medium	Strong	Strong	Strong

As can be seen from the above table, Shanxi Province's fixed asset investment price index IPI, industrial producer fuel power purchase price index FPI, and consumer price index CPI are strongly correlated with oil price index OPI (>0.5), indicating that oil price fluctuations will strongly affect Shanxi CBM assets investment and the fuel power costs, management expenses, sales expenses, workers' wages, etc. in development process; and Shanxi Province oil and gas exploration industry ex-factory price index GPPI, total natural gas energy consumption chain index GPI is moderately correlated with oil price index OPI (0.3-0.5), indicating that oil price fluctuation has an impact on China's natural gas market and prices, but the impact is not significant.

It should be noted that global oil price are weakly related to the consumer price index CPI in general, but Shanxi Province is China's major energy output province, so the strong correlation between CPI and OPI can also be explained.

2.3 Regression analysis and impact quantification

In terms of the impact of global oil price fluctuations on natural gas prices in Shanxi Province, the problem is more complicated: on the one hand, CBM in Shanxi Province is mainly used for winter heating and daily use of residents. To protect people's livelihood, the Chinese Central Government and the Shanxi Provincial Government have strong control over natural gas price, and the fluctuation of global oil price cannot be effectively transmitted to the price of CBM in Shanxi Province. From the GPPI data in Table 1, it can be seen that the natural gas price in Shanxi Province has changed little in the past decade, and the fitting result As shown in Figure 3 below (left), OPI and GPPI are medium correlation. The goodness of fit (R^2) of regression equation is 0. 15. The fitting effect is weak. The regression result is invalid. The price of CBM in Shanxi Province is basically not affected by fluctuations in global oil price.

On the other hand, the Chinese government is undergoing a market-oriented reform of the natural gas pricing mechanism. The pilot gas price in the pilot province is linked to the fuel price (60% fuel oil, 40% liquefied petroleum gas) according to the “market net return method”. China's CBM prices will be largely influenced by

global oil prices through fuel prices in the future, so two scenarios will be discussed in subsequent studies. If the natural gas marketization pricing reform occurs in Shanxi Province, the petroleum product fuel price index PPPI is selected as the index of CBM price, and the data of 2006-2017 is also selected for fitting. The fitting result is as shown in Figure 3 (right), and the regression equation fits goodness R^2 is 0.93, the fitting effect is very good. The PPPI increases by 0.34% for every 1% increase in the oil price index. It is believed that when the natural gas marketization pricing reform occurs in Shanxi Province, the price of CBM will change according to this ratio.

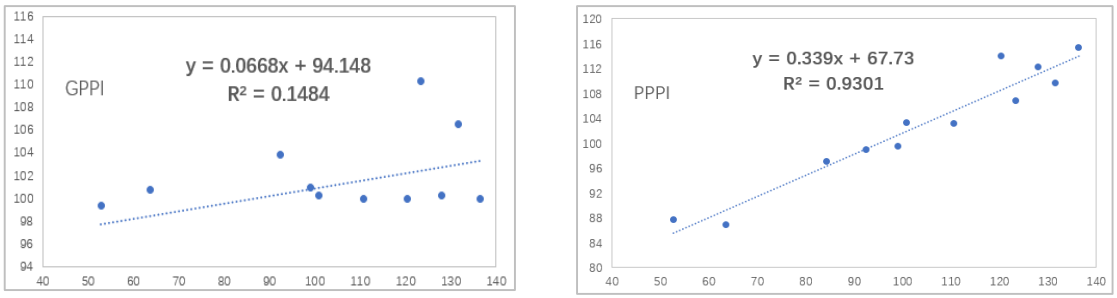

Figure 3 Linear fitting results of oil price index index OPI and GPPI, PPPI

There is a strong correlation between the global oil price and the exploration and development investment and various operating costs in the process of CBM exploration and development in Shanxi Province. Therefore, the regression analysis is further carried out. The fitting results of OPI with other parameters are shown in Figure 4 below:

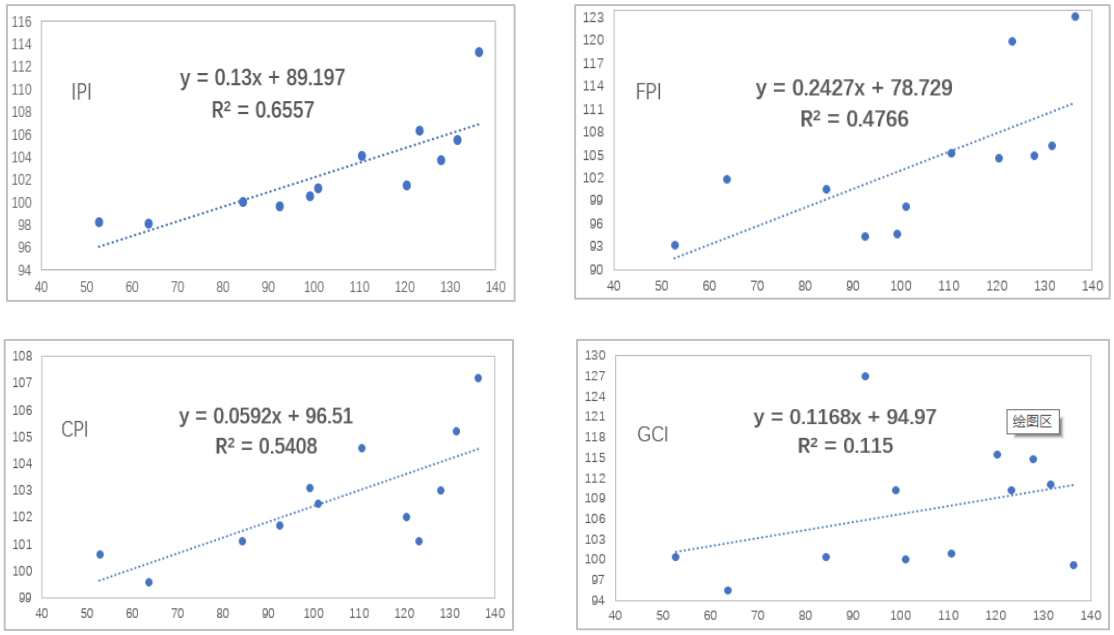

Figure 4 Linear fitting results of oil price index OPI and other evaluation parameters affected by it

In summary, IPI, FPI and CPI are all strongly correlated with OPI. According to the regression equation, IPI increased by 0.13%, FPI increased by 0.24%, CPI increased by 0.06% for every 1% increase in OPI, and the result is reliable. Fluctuations will affect the cash outflow of CBM development in Shanxi Province through these indices.

GCI are also moderately correlated with OPI, and the goodness of fit (R^2) of the regression equation is 0.12, which is considered to be invalid. It is believed that the impact of global oil price fluctuations on the scale of natural gas consumption in Shanxi Province at this stage cannot be determined. At this stage, China's natural gas consumption is in a period of rapid growth. The impact of oil price fluctuations on the size of the natural gas market may not be accurately measured with the rapid growth of demand. Therefore, the impact of global oil price fluctuations on the development efficiency of CBM through the scale of natural gas market is ignored. .

The quantitative results of the impact of global oil price fluctuations on CBM development benefit evaluation indicators are shown in Table 4 below:

Table 4 Changes in relevant parameters of CBM development benefits in Shanxi Province when the global oil price changes by 1%

Evaluation parameter	CBM price		Development investment	Fuel power fee	Running Cost	Other operating costs	Market size
	No reform	reform					
index	GPPI	PPPI	IPI	FPI	/	CPI	GCI
Degree of change (%)	0	0.34	0.13	0.24	0.18	0.06	0

3. Sensitivity analysis of Shanxi CBM development benefit and the results

Sensitivity analysis is an analysis method of uncertainty that changes the input value of relevant influencing factors one by one from a quantitative point of view and explains the degree of change of the affected indicators. The essence is to describe the change degree of output variables caused by input variables through a quantitative relationship model. (Y Jia,2015). For the affected factor of Shanxi CBM development benefit, the impact degree of each affected factor on the final development benefit is different. The NPV is the final indicator of CBM development benefit, and the NPV is used to analyze the sensitivity of various indicators affected by oil price fluctuations. The higher the sensitivity, the greater the impact on the NPV.

3.1 Brief introduction of CBM development case block

China's CBM development and utilization started relatively late, there has not been a CBM block that has been mined so far. Therefore, a typical CBM development block in Baode, Shanxi Province is selected as the baseline scenario. The gas production data are shown in Table 5 below. The basic parameters of the single well and some financial cost data are shown in Table 6 below.

Table 5 Annual production of gas production years in CBM development case block

production years	well number	Annual production capacity (1×10^8 m^3)	production years	well number	Annual production capacity (1×10^8 m^3)
1	180	0	14	1288	6.791
2	574	2.397	15	995	5.973
3	685	5.268	16	884	5.348
4	685	7.025	17	884	4.981
5	685	7.211	18	884	4.628
6	685	6.882	19	838	4.079
7	874	6.576	20	649	3.049
8	874	6.648	21	538	2.418
9	874	6.465	22	414	1.798
10	1063	6.205	23	225	0.977
11	1063	6.433	24	225	0.902
12	1063	6.435	25	225	0.843
13	1288	6.344	Total	/	115.676

Table 6 Financial cost of the single well in CBM development case block

Type	Name	Unit	figure
basic data	Gas production period	year	25
	Commodity rate	%	90
	Gas price	CNY/m^3	1.13
	Benchmark discount rate	%	10
	Subsidy degree	CNY/m^3	0.3
Construction	Exploration investment	1×10^4 CNY	18.42

Investment	Development investment	1×10^4 CNY	235
Operating cost	Raw material	1×10^4 CNY/year	5.032
	Fuel power fee	1×10^4 CNY/year	1.282
	Production workers' wages and benefits	1×10^4 CNY/year	7.489
	Other direct fees	1×10^4 CNY/year	3.66
	Project management fee	1×10^4 CNY/year	1.83
	sales expense	1×10^4 CNY/year	0.915
Financing flow	Single well liquidity	1×10^4 CNY/year	6.725
	Long-term borrowing effective annual interest rate	%	4
	Loan ratio	%	70

3.2 Sensitivity analysis of development benefits to evaluation parameters

LY Xia (2016,2017) pointed out that in the current technical and economic conditions, the range of various economic evaluation indicators varies within ±20%. Based on the gas production and financial situation of the case block scenario, we calculate the sensitivity of NPV to various index factors, set the step size at 5%, and plot the sensitivity analysis of each factor, as shown in Figure 2 below:

The sensitivity analysis curve is fitted to obtain the slope of the sensitivity curve, which is the sensitivity of the NPV to the economic impact factors. The fitting results are shown in Table 7 below.

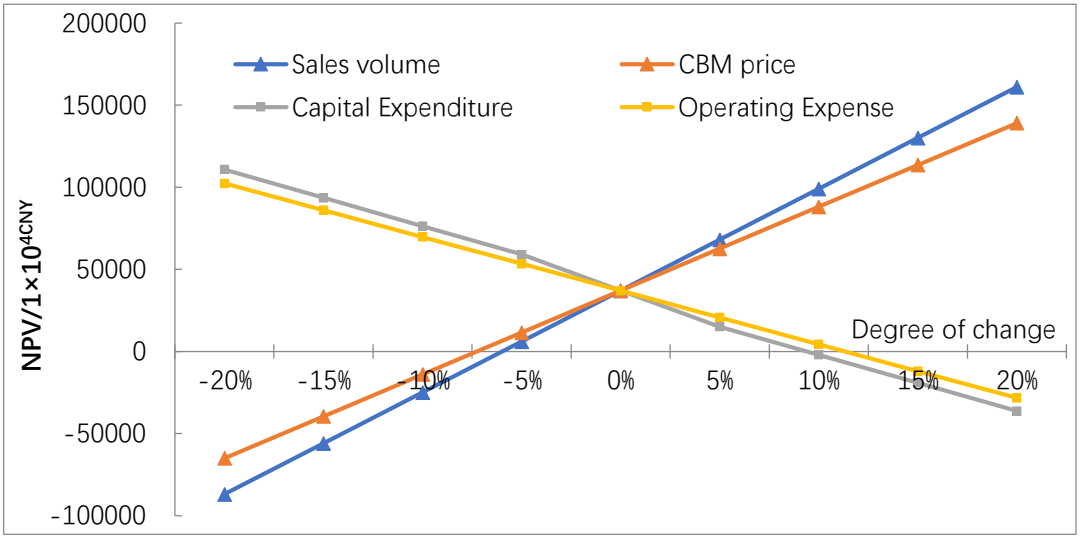

Figure 2 The NPV Sensitivity analysis of CBM case block

Table 7 The degree of change in NPV for every 1% change in economic evaluation indicators

Economic evaluation index	Construction Investment	Operating cost	CBM price	Sales volume
NPV change (%)	-10.14	-8.82	13.77	16.74

3.3 Development Benefits Affected by Oil Price Fluctuation

According to the transmission mechanism of the impact of oil price on the development benefit of CBM, the impact of oil price fluctuation on the affected factor of Shanxi CBM development benefits, and the results of sensitivity analysis of Shanxi CBM development benefits, we finally quantify the impact of global oil price fluctuations on the benefits of CBM development in Shanxi, the results are shown in Table 8 below:

Table 8 Conduction process and calculation results of the impact of global oil price changes on the development of CBM in Shanxi Province

Global oil price change (%)	+1		+1			+1	
Affected factor	CBM price		Construction Investment	Operating cost			Sales volume
Evaluation parameter	No reform	reform	Land resource compensation fee; Exploration and development investment	Fuel power fee	Running Cost	Other operating costs	Market size
Parameter index	GPPI	PPPI	IPI	FPI	/	CPI	GCI
proportion	/	/	/	6.35%	80.07%	14.58%	/
Degree of change	0%	0.34%	0.13%		0.17%		0
Degree of change in NPV	0%	4.682%	-1.318%		-1.499%		0%
NPV total	-2.818% , the non-reform scenario (NOW); +1.864%, the reform scenario (FUTURE)						

Conclusion

1. The impact of oil price on the development benefit of CBM is mainly reflected in the construction investment cost and operating cost. For every 1% increase in oil price, CBM development and construction investment in Shanxi Province increased by 0.13%, fuel power fee increased by 0.24%, operating cost increased by 0.18%, and other operating costs increased by 0.06%. The overall operating cost increased by 0.17%. However, at this stage, the price of CBM is basically not affected by global oil price. Shanxi's rapidly growing demand for natural gas obscures the extent to which the market is affected by global oil price fluctuations

2. Surprisingly, If Shanxi does not have the natural gas price marketization reform in the future, a 1% increase in oil prices will result in a 2.818% drop in CBM development revenue. This is because the price of CBM in China is regulated by the government, and the fluctuation of global oil price has little impact on the price of natural gas in Shanxi Province. When the oil price rises, the investment and operating cost rises, but the CBM price does not increase, which leads to the loss of development benefits, and suppresses the enthusiasm of energy companies to develop CBM. After scenario analysis, If Shanxi carries on the natural gas price marketization reform, and the CBM market price is linked to fuel prices, CBM development revenues will rise by 1.864% when global oil price rise by 1%.

3. For the local CBM development in Shanxi Province of China, with the premise of the current subsidy policy and price formulation policy, the recent decline in oil prices will benefit the development of the local CBM industry.

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