# A real options based assessment on coal bed methane investment policy with a case study in China

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## Abstract:

In this paper, a real options based bidimensional binominal lattices model for the investment of coal bed methane (CBM) is conducted, applying which investment policy affecting the project value and the investment behavior are explored. The empirical results show that the model can make a better explanation to the phenomena that the CBM industry has developed slowly in recent years. It is found that the current investment environment is not suitable to attractive investment in the CBM industry at current stage. Among various factors, a higher price of CBM has the most significant effect on stimulating investment to CBM industry. More subsidy is an effective policy tool to stimulate investment and develop the CBM industry more quickly in China.

**Key words: coal bed methane; policy evaluation; real options; China**

## 1. Introduction

Coal bed methane (CBM) is a kind of unconventional nature gas found in coal seams, which may make a significant contribution to meet the increasing natural gas need in China. The exploration and development of CBM will not only decrease accidents, but also reduce GHG emissions during the process of coal mining, since the greenhouse-effect of methane is 20 times of $CO_2$.

China has abundant CBM resource, and the geological CBM resource volume is the third largest in the world next to Russia and Canada. The methane-bearing area is of 41.54×104 km2 under the buried depth less than 2000m in 45 coal-accumulating basins and the geological reserves is 36.8×1012 m3(Liu CL etal, 2010), which is equivalent to the conventional gas reserve. According to the China's 11th Five-Year Plan, great efforts should be made so as to have production volume to reach 100×108m3 per year, including surface production volume of 50 ×108m3, and the utilization volume to reach 80×108m3 per year in 2010. However, these targets had not been achieved at the end year of the 11th Five-Year Plan. In 2010, the total production volume of CBM reached only about 86×108m3, the utilization volume 34.06×108m3 and the surface production volume 14.5×108m3. Therefore, it is important to explore why CBM industry development was so slow from 2006 to 2010, and how to attract more investment to CBM gas exploitation so to promote the development of the CBM industry in the future.

There have been some discussions on the obstacle of the development of the CBM industry in China and the respective solution to the problem. Qin (2006) discussed some technical problems on the CBM exploration. Liu (2009) gave a systematic summary on the policy system (subsidy, tax, price, the management of the right of exploration and mining and so on) stimulating the CBM industry development. Yuan (2009), Zhao (2011) summarized the foreign experience of the development of the CBM industry and pointed out the problems that exist in China's policy and management. Luo (2010) conducted an economic evaluation of the CBM target areas in China and made an analysis of the policy affecting the industry development with DCF method.

However, these discussions referred to above mainly focused on the qualitative analysis of the problem, and few gave quantitative analysis of the problem from the perspective of the investment. Even these few quantitative works were conducted with the traditional DCF method, which can not incorporate the uncertainties and the managing flexibility into the model. As a consequence, it can not make an objective evaluation of the investment, nor could it solve the problem of the investment timing optimization.

A CBM project requires huge investment, with long-term lifecycle and high risks. Confronted with the risk, investors have options to invest or to wait, which is similar to the financial option——investors won't conduct the option until the favorable conditions emerge. This option increases the project value by avoiding possible irreversible loss. As a consequence, the investors of the CBM project have the option to delay the investment-delay option (McDonald and Siegel, 1986; Ingersoll and Ross, 1992) when the circumstance is not favorable enough, and the investment and development of the whole industry will become slowly. Real option methods have the advantage to describe and solve the problem with the characteristics referred above. Emiel van der Maaten (2010) investigates the effect of a Dutch government subsidy program on the investment in a solar hot water system based on market priced risk. Shun-Chung Lee and Li-Hsing Shih (2010) evaluates quantitatively the policy value provided by developing renewable energy (RE) in the face of uncertain fossil fuel prices and RE policy-related factors with the real option methods. Stein-Erik Fleten et al(2011) investigate whether uncertainty with respect to the introduction of a market for green certificates has affected the timing of investments in small hydropower plants Norway from 2001 to 2010 using real options theory and a multivariate discrete choice model, and it is found that real options models give better explanation of investors' behavior compared to traditional net present value analysis.

In this paper, a real options based model with bidimensional binominal lattices was built, and a project value evaluation is conducted with the Han Cheng CBM target area in Shanxi province as a case study. Then the effect of the related policies on the project value and the investment behavior are analyzed. Based on the analysis above we try to answer the following questions: why the CBM industry in China still developed slowly under current conditions of technology, infrastructure and regulations? Which policy needs to be adjusted and improved to encourage the investment? And what policy mix is the most effective policy tool? As a consequence, the policy mix to stimulate the investment on CBM industry is proposed.

## 2 Methods and model

### 2.1 Modeling uncertainties

1) The source of uncertainty

A CBM project requires huge investment, with long-term lifecycle and high risks. The validity of investment profit in CBM projects is affected by many uncertain factors. According to the current concrete conditions in China, gas price is the most important uncertainty among the uncertainties referred above, especially when the natural resource pricing mechanism is under reform (Dong, 2010). In addition, the basic infrastructure of the CBM pipeline is imperfect, and the production of the CBM is mainly used to satisfy the local needs (Zhang, 2009). So the market demand becomes another important uncertainty affecting the investment decision. As a consequence, the price and the market demand are incorporated into the model as the source of the uncertainty and the other factors are specified exogenously according to the current conditions and future expectation.

2) The description of the uncertainty

It's assumed that the stochastic process for the evolution of the CBM price and the market demand follow the Geometric Brownian Motion:

$$
\begin{aligned}
dP_t &= \alpha_p P_t dt + \sigma_p P_t dW^P{}_t, \\
dC_t &= \alpha_c C_t dt + \sigma_c C_t dW^C{}_t, \\
dW_t^P dW_t^C &= \rho dt.
\end{aligned}
\tag{1}
$$

where $P_t$ and $C_t$ denote the CBM price and the market demand, and $E(P_t) = P_0 e^{\alpha_p t}$, $E(C_t) = C_0 e^{\alpha_c t}$, $\alpha_p, \alpha_c$ stands for the expected growth rate of the price and the market demand, and $\sigma_P, \sigma_c$ the instantaneous volatility of CBM price and demand. $dW^P{}_t, dW^C{}_t$ is the increment to a standard Wiener process respectively and they are assumed to be normally distributed with zero mean and variance dt. $\rho$ is the coefficient correlation between $P_t$ and $C_t$.

The Geometric Brownian Motion is the limiting form of the binomial tree lattice when the time interval approaching zero, so it can be adequately approximated via a multi-period binomial process in which the random variable in the next period increases or decreases from its current level (John C. COX etal, 1979). As two stochastic processes $P_t$ and $C_t$ were considered in our model, bidimensional binominal lattices was employed (Boyle, p.p., 1988). The CBM price and the market demand in period t $(P,C)_t$ will increase or decrease in the period t+1, and end up with four possible results: $(P^u, C^u)_{t+1}$, $(P^u, C^d)_{t+1}$, $(P^d, C^u)_{t+1}$, $(P^d, C^d)_{t+1}$, where the superscript "u" means the increase of the CBM price (or the market demand), and "d" means the decrease at period t+1, and $p_{t+1}{}^{uu}$, $p_{t+1}{}^{ud}$, $p_{t+1}{}^{du}$, $p_{t+1}{}^{dd}$ are the occurrence probability of $(P^u, C^u)_{t+1}$, $(P^u, C^d)_{t+1}$, $(P^d, C^u)_{t+1}$, $(P^d, C^d)_{t+1}$ respectively, which can obtained according to Brandimarte (2006.).

### 2.2 The investment decision process

The CBM price and the market demand are the main sources of the uncertainty that affect the investment decision. What's more, the investment cost, operating and maintaince cost, tax and subsidy would also affect the economic performance of the investment. In any period t, the decision maker makes an evaluation whether it is better to invest immediately than to delay the investment by comparing the two expected net cash flows. If the expected net cash flow of investing immediately is more than that of delaying investment, the decision maker will make the investment in period t, or else the investor will delay the investment and wait for the emergence of better conditions in the next period.

1) The project value and the investment decision in period t (t≤T)

In the last period T (the deadline of the mining right), the project value $W_T$ would arise as the maximum between making the investment in the project in exchange for nothing and zero: $W_T = \max(NPV_T, 0) = 0$, and we will decide to give up the investment in period T.

In earlier period t, the best option is chosen between to invest and to continue waiting at any possible node *(P,C)t*, and we can get the project value $W_t$ at period t:

$$W_t = \max(NPV_t, \beta(p_{uu}W_{t+1}^{++} + p_{ud}W_{t+1}^{+-} + p_{du}W_{t+1}^{-+} + p_{dd}W_{t+1}^{--}) \quad (2)$$

At period t, investing yields the $NPV_t$ for sure; waiting and delaying the investment decision allows to get the expected future cash flow of the investment opportunity (the sum of the four possible expected project values at period t+1 ($W_{t+1}^{++}, W_{t+1}^{+-}, W_{t+1}^{-+}, W_{t+1}^{--}$) weighted by their respective probabilities) discounted by the $\beta$.

And we make the decision according to the following rules:

$$\begin{cases} \text{Make investment} \quad \text{when } NPV_t > \beta(p_{uu}W_{t+1}^{++} + p_{ud}W_{t+1}^{+-} + p_{du}W_{t+1}^{-+} + p_{dd}W_{t+1}^{--}) \\ \text{Delay and wait} \quad \text{when } NPV_t < \beta(p_{uu}W_{t+1}^{++} + p_{ud}W_{t+1}^{+-} + p_{du}W_{t+1}^{-+} + p_{dd}W_{t+1}^{--}) \end{cases}$$

2) The earliest time and the probability to make investment

Under the assumption of the bidimensional binominal lattices model in Fig 1, there would be $N_t$ nodes in period t, which means there would be $N_t$ possible results for the CBM price and market demand *(P,C)t* in period t, and $N_t = t^2$ according to the formula (4). Assume that the investment decision nodes turn up first time in the period t', and there is no investment decision node before period t', then t' is defined as the earliest time to invest. If the number of the investment decision nodes is m（$m \le N_t$）in period t', and the respective probability for each node is $p^i_{t'}$（$i = 1, 2 \ldots\ldots m$）, then the probability to make investment in period t' is $p_{t'} = \sum_{i=1}^{m} p^i_{t'}$.

What we concern about in this work is the effect of the policy system on the CBM project value $W_1$, the earliest time t' to make investment and the respective probability to make investment $p_{t'}$.

3) The expected net present value of the project when making investment

According to the concrete situations of the CBM exploration investment in China, there are several factors affecting the expected net present value of the project, including the revenues from selling the CBM product, the government subsidy, investment cost, production and operation cost and tax which includes the value added tax, corporate income tax and other tax. Then we can get the expected net present value of the project:

$$NPV_t = PV_t^{\text{CBM}} + PV_t^{Subsidy} - PV_t^{Investment} - PV_t^{OC} - PV_t^{Tax} \quad (3)$$

and

$$
\begin{aligned}
PV_t^{CBM} &= \sum_{i=t+1}^{T} C_i \times \overline{P}_i \times DF_i, \\
PV_t^{Subsidy} &= \sum_{i=t+1}^{T} C_i \times SPCM \times DF_i, \\
PV_t^{OC} &= \sum_{i=t+1}^{T} (Production_i \times OC) \times DF_i, \\
PV^{tax} &= \sum_{i=t+1}^{T} [(Commodity_i \times \overline{P}_i \times VAT \times OT + (C_i \times \overline{P}_i - \\
&\quad Production_i \times SPCM - C_i \times \overline{P}_i \times VAT \times OT) \times CIT] \times DF_i
\end{aligned}
\tag{4}
$$

Where

$PV_t^{CBM}$ and $PV_t^{Subsidy}$ represent the revenues from the CBM product sales and the government subsidy, $PV_t^{Investment}$ and $PV_t^{OC}$ are the investment outlay and the operation and production cost of the project, $PV_t^{Tax}$ represents tax revenue expenditure; $\overline{P}_i$ is the expected price of CBM product in period i, $DF_i$ is the discount rate in period i, $SPCM$ is the subsidy per cubic meter, $Production_i$ and $C_i$ is the production volume and the demand of the CBM product, $OC$ is the operation and production cost per cubic meter production, $CIT$ ,$VAT$ and $OT$ represent the corporate income tax rate, the value added tax rate and Other local tax rate.

## 3 Parameter estimation

Hancheng CBM target in Shanxi province is an important CBM target with great potentiality to be exploited. So he evaluation of the investment is conducted with it as a case study. The project parameters of Hancheng CBM target are mainly from EU-China Energy and Environment Programme (Europe Aid/120723/D/SV/CN) research (China University of Petroleum (Beijing), 2008).

The lifetime of the license for exploitation is 30 years for large-scale mine construction in China (the State Council, 1998), and the decision-making time is set as 30 years. Investment cost and operation and production cost are 11.7 Billion RMB and 0.320 RMB/m3. The pricing of the CBM refers to the nature gas pricing. In 2005, the price of the nature gas is 0.700 RMB/m3 (NDRC, 2005), which is one fourth of the LPG price, one third of the fuel oil, and half of the import price (NDRC, 2010). So the current price is set as 0.700 RMB/m3 and the future expected target price 2.10 RMB/m3 (3*0.7=2.10 RMB/m3). The current market demand is 1.73 Billion m3 and the market demand of the CBM is closely related to the level of urbanization and the demand will increase with the improvement of the urbanization in China. In 2005, the Town populations was 0.520 billion, (World Bank, 2010), and it will reach 1 billion in 2030 according to the forecast of World Bank and McKinsey (China net, 2011). So we set the expected market demand in period T as 3.32 Billion m3(10/5.2*1.73). In addition, the value added tax (VAT) will be returned to the corporation after collection. (Ministry of Finance, State Administration of Taxation，2007)

Based on the current price, the current market demand, the future expected target price and the future expected market demand, the drift rate will be obtained according to the equation(1). The estimates of variance rate of the CBM price, the market demand and the correlation coefficient between them can be obtained using the CBM price data and market demand data according to Abadie LM and Chamorro JM. (2008). However, the two sets of the data are unavailable. Considering that the CBM price pricing will refer to the alternative energy price which is determined by the market in future pricing reform, the Brent oil price (1987-2010) was chosen as the substitute. What's more, we choose the town populations data (1987-2010) as the substitute for the market demand data.

## 4 Result

### 4.1 The evaluation results with NPV and the Real Option (RO) method

The evaluation results with NPV and RO method are shown respectively in Table 1. The project value with NPV method is 1.51 billion RMB, and the rate of return on investment is 12.9% (1.51/11.7236*100%=12.9%). So the investment efficiency of the CBM project is high and the investment should be made immediately according to the NPV rules. While the project value evaluated with RO method is 4.31 billion RMB, and it's better to delay the investment and wait at least for 4 years. The result of RO method shows that to invest immediately is not the best decision choice because it means that the option value of 2.80 billion RMB was given up. Although the uncertainty of the price and the demand increase the project value, the investment decision is also delayed. As a result, the RO method can give a possible explanation why the CBM industry developed slowly in China.

Table 1 Comparison of the evaluation results between NPV and the RO method

<table>
<tr><th>Method</th><th>Project value (Billion RMB)</th><th>Option value (Billion RMB)</th><th>Decision on when to invest</th></tr>
<tr><td>Traditional NPV</td><td>1.51</td><td rowspan="2">2.80</td><td>Make investment in 1st year</td></tr>
<tr><td>RO</td><td>4.31</td><td>Delay investment and wait 4 years</td></tr>
</table>

From the perspective of the real option, the policy system is not favorable enough to encourage the decision maker to make the investment immediately and it is still necessary to adjust the policy setting so that the option value loss could be made up if the investment were made without delay.

### 4.2 Evaluation of policies and market conditions

A scenario analysis was conducted on the effect of the policy and market conditions on the project value and the investment decision, and the scenario setting is shown in Table 2.

Table 2 The scenario setting of the policy and market variable

| Policy variable | *P(0)* (RMB/m3) | *P(T)* (RMB/m3) | $\sigma_P$(%) | $\alpha_c$(%) | *SPCM* (RMB/m3) | *CIT* (%) |
|---|---|---|---|---|---|---|
| Case1 | **0.70～1.40** | 3.00 | 0.24 | 2.00 | 0.20 | 25.00 |
| Case3 | 0.70 | 3.00 | **0.05～1** | 2.00 | 0.20 | 25.00 |
| Case5 | 0.70 | 3.00 | 0.24 | 2.00 | **0～0.60** | 25.00 |
| Case6 | 0.70 | 3.00 | 0.24 | 2.00 | 0.20 | **0～50.00** |

1) The current price of CBM product

The pricing reform of the CBM is under discussion in China. And the chief defect of the current pricing system leads to the low price of the CBM product, which may result in the waste of the resource and the slow development of the CBM industry (Li, 2009). We make an analysis of the effect of the current CBM price level on the project value and the investment decision and the results are shown in Fig 1.

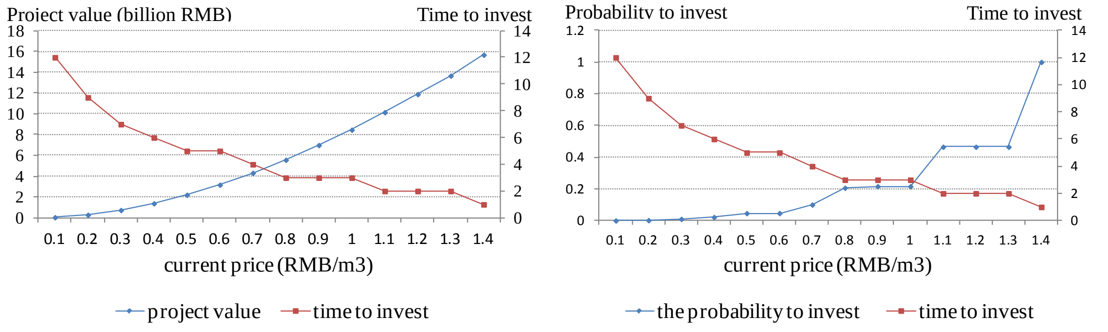


Fig 1 The effect of the current price on the project value and the investment decision

The project value increases rapidly with the current price improvement, and the investment decision is shift to an earlier period with the probability to invest increasing. When the current price increases from 0.7RMB/m3 to 1.4 RMB/m3, the project value increases from 4.3 billion RMB to 15.6 billion RMB accordingly and it's better to execute the investment immediately.

2) The price risk

Market pricing is the trend of the pricing reform, and the price risk will increase accordingly with the pricing reform. How the price risk changes influence the project value and the investment decision is analyzed and the result is shown in Fig 2.

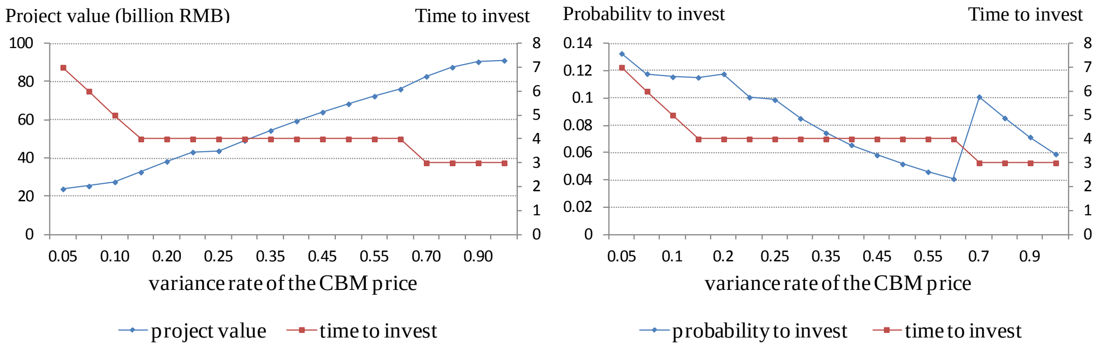


Fig 2 The effect of the CBM price uncertainty on the project value and the investment decision

First of all, the increase in the price uncertainty leads to the increase of the project value. This is in accordance with the main idea of the real option: the decision maker with decision flexibility would avoid more possible loss should the product price and demand drop dramatically and obtain more revenues should the conditions become more favorable. In addition, the investment may become earlier as the price uncertainty increases because the wide price fluctuation range will make it easy to reach the critical price.

The empirical result shows that when the variance rate of the price increases from 0 to 0.15, the time when to invest becomes earlier: from the seventh year to the forth year and the probability changes little. So it can be concluded that the increase in the uncertainty will encourage the investment. However, when the variance rate increases from 0.15 to 0.6, the time when to invest doesn't change and the probability decreases. So it will delay the investment when the uncertainty increases. The result is in accordance with that of Sudipto Sarkar (2000): the increase in the price uncertainty will promote the investment when the uncertainty is low and negatively affect the investment when the uncertainty is high. In current situation, the increase in the price uncertainty will promote the investment.

3) The subsidy

The price subsidy may make up a possible temporary loss of the CBM producer especially under the circumstance of low regulated price and it is necessary for the sustainable development of the CBM industry. The current subsidy level is 0.2RMB/m3. The effect of the subsidy improvement on the investment is what we concern about. The project value and the investment decision is analyzed under different subsidy level and the result is shown in Fig 3.

The project value increases with the subsidy increasing. Also the time when to invest becomes earlier and the probability to invest also increases. According to the result, the investment can be made without any delay when the subsidy reaches 0.6RMB/m3 and the corresponding project value is 8.5 billion RMB. So it is an effective policy tool to stimulate the investment.

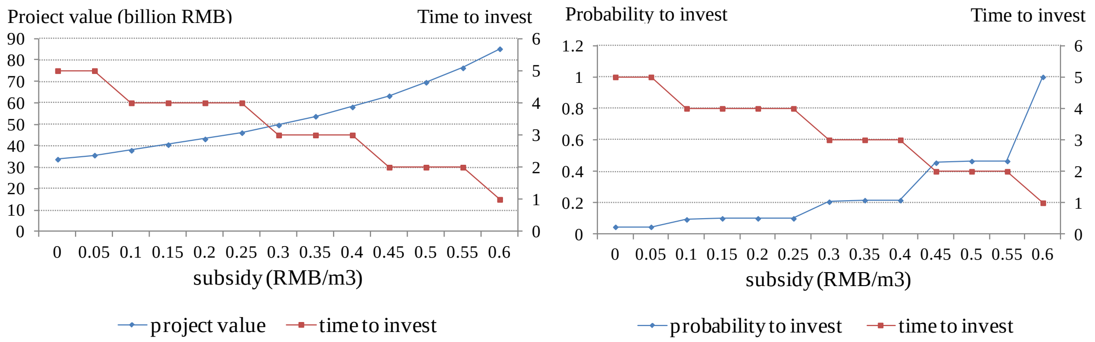


Fig 3 The effect of the CBM price uncertainty on the project value and the investment decision

4) Corporate income tax

The tax has sound effect on the efficiency of the investment. The value added tax is returned to the corporation after collection and the surface production CBM product has been exempted from the resource tax. So our attention is concentrated on the corporate income tax analysis. The effect of the corporate income tax on the project value and investment decision is shown in Fig 4.

The project value increases linearly with decreased corporate income tax. Also the time when to invest becomes earlier and the probability to invest also increases. According to the result, the time to invest is one year earlier than the base scenario (25%) when the corporate income tax decreases to 10% and the probability increases from 10% to about 20%. However the corporate income tax change has little effect on the investment decision when it decreases from 10% to 0, and the investment still should be delayed at least 3 years even if the tax were exempted. It is because the object of tax is the profit of the investment. However, whether the investment can make profit is still a first question for the decision maker and then it is the reduction of the tax. So the effect of the corporate income tax change will be limited.

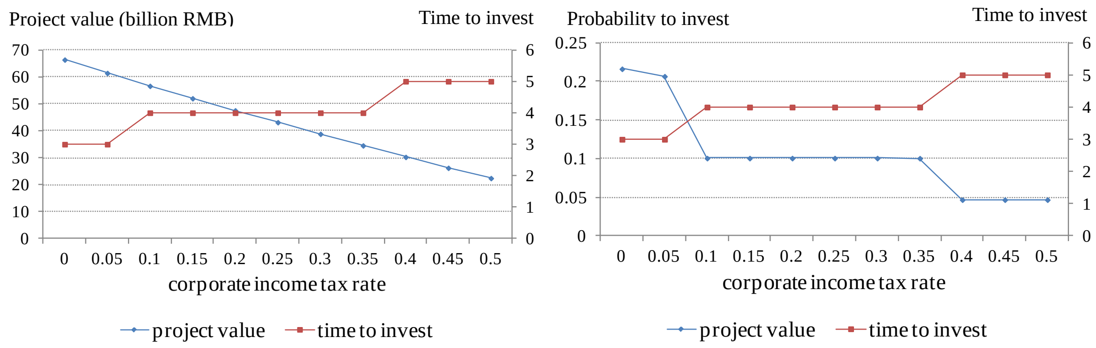


Fig 4 The effect of the corporate income tax on the project value and the investment decision

5) The comparison of the policy effect

The comparison analysis was performed to determine the main factors causing the most variability in the project value and the decision making. The procedure is to calculate the benchmark value of each policy variable, and then to change respectively the benchmark value of each input variable from 0 to 100% when the other input variables are kept unchanged, and then to study how the project value and investment decision (the time to invest) changes with the changes in each input variable.

First we make a comparison of the effect on the project value for different policy variables, as is shown in Fig 9(A). According to the result, the project value is most sensitive to the current CBM price, then it is the price uncertainty and the corporate income tax, and the last is the subsidy.

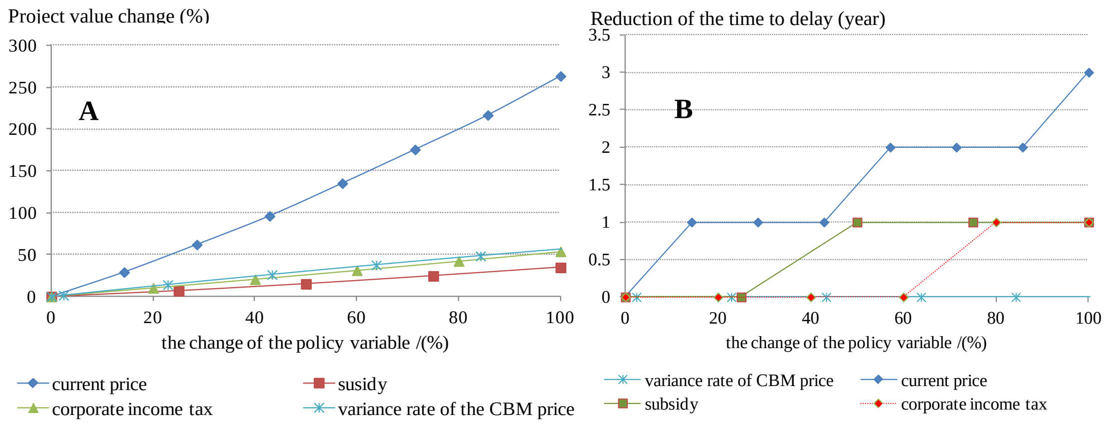


Fig 9 Comparison of the effect on project value and investment decision for different policy variables

Then we compare the effect on the decision making for different policy variables, as is shown in Fig 9(B). The result shows that the current CBM price also has the most significant effect on the time when to invest, then it is the subsidy and corporate income tax, and the last is the price uncertainty.

## 5 Conclusion

In this paper, a real options based bidimensional binominal lattices model for the investment of coal bed methane (CBM) is conducted, applying which investment policy affecting the project value and the investment behavior are explored.

According to NPV rules, the investment might be executed at a moment t when NPV>0, while it might be better to delay the investment decision according to the RO evaluation. The empirical results show that the model can make a better explanation to the phenomena that the CBM industry has developed slowly in recent years. It is found that the current investment environment is not suitable to attractive investment in the CBM industry at current stage.

Among various factors, a higher price of CBM has the most significant effect on stimulating investment to CBM industry. More subsidy is an effective policy tool to stimulate investment and develop the CBM industry more quickly in China.

This paper is concentrated on policies that affect the economic viability of investment in CBM area, and provides a basic model to analyze investment behavior. However there are some other factors including technology improvement, resource management policies, pipeline construction and so on, should be considered, which will be the further research content.

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