Financial model and economic evaluation of polymetallic nodules development in the Area

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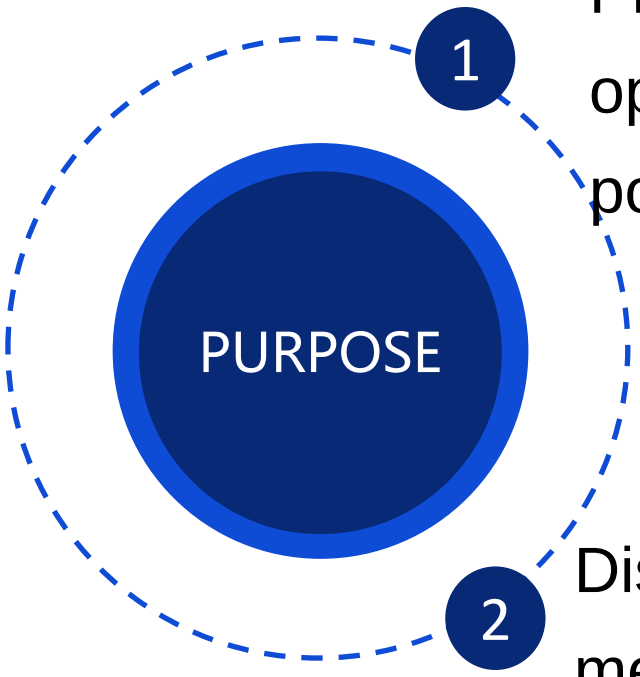


Provide a method for predicting the opportunity of commercial exploitation of polymetallic nodules in the area.

Discuss the royalty rates for payment mechanism of exploitation regulations.

Outline

1. Modeling and evaluation method
2. Determination of model input parameters
3. Economic indicators of the project
4. Analysis and Comparison of royalty rates

1. Modeling and evaluation method

Two models are applied for this research.

Model 1: Discounted Cash Flow Model

Net Present Value

$$NPV = \sum_{t=0}^{n} (CI_t - CO_t)(1 - i_0)^{-t}$$

Internal Rate of Return

$$NPV(IRR) = \sum_{t=0}^{n} (CI_t - CO_t)(1 - IRR)^{-t} = 0$$

Dynamic Investment Pay-back Period

$$\sum_{t=0}^{Pt} (CI_t - CO_t)(1 - i_0)^{-t} = 0$$

■The Discounted Cash Flow model is used for profitability assessments from a financial perspective. Three kinds of evaluation index including Net Present Value (NPV), Internal Rate of Return (IRR) and Dynamic Investment Pay-back Period are calculated.

■ If the NPV is positive and the IRR is greater than or equal to Hurdle Rate, the project is considered acceptable otherwise the project is rejected. A hurdle rate is the minimum rate of return on a project or investment required by a manager or investor.

1. Modeling and evaluation method

Model 2: Break Even Point Model

Breakeven Grade

$$B=c/P$$

B —— cutoff grade/breakeven grade
c —— production cost per ton
P —— metal price
Example：
copper price P=6000 dols/t， production cost per ton c=30 dols/t，
B = c/P= 30/6000=0.5%

Nickel Equivalent

$$NiEqv = \frac{\sum_{i=1}^{4} P_i R_i M_i}{P_{Ni}}$$

Index “i” refers to the four metals considered in this study, namely Mn, Cu, Ni, Co.
Pi——metal price
Ri——recovery
Mi——metal grade

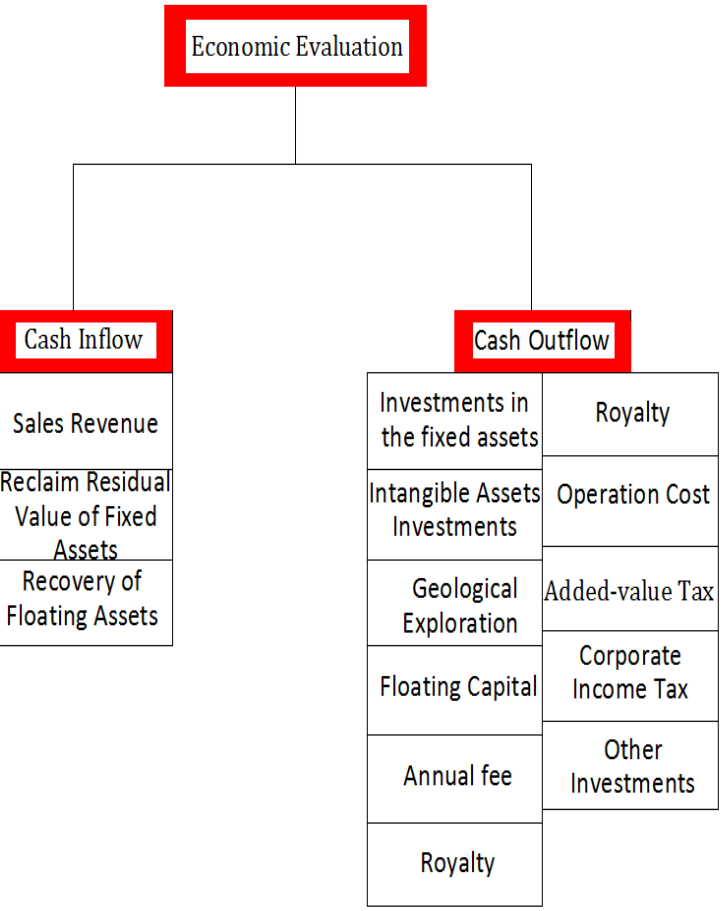
A Break Even Point model is built and used to determine the breakeven grade for profit and loss of deep sea mining.
This is a relatively and fast evaluation method for macro economyand it is widely used in land mining.

B < NiEqv ⟹ profit

B > NiEqv ⟹ loss

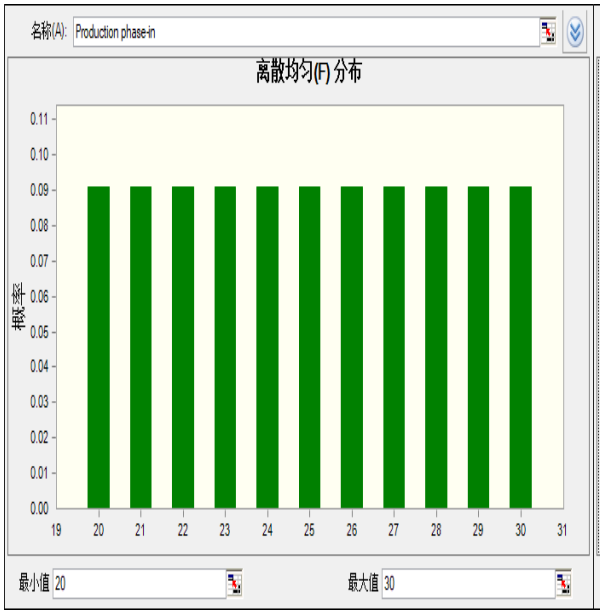
2. Determination of model input parameters

Parameter category and determination:



Parameter uncertainty and processing method:

uniform distribution



triangular

The probability distribution is divided into uniform distribution and triangular distribution.

2. Determination of model input parameters

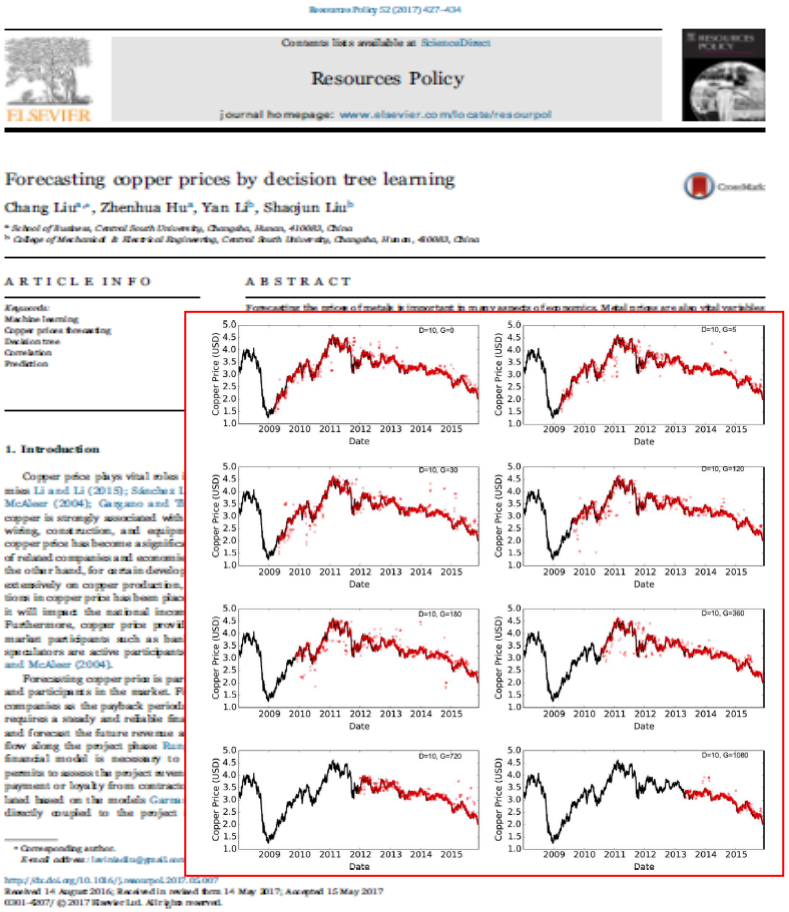
Basic parameters and distribution

Sensitivity Factor		Distribution Type	Expected Value	Distribution Interval
Annual Ore Production（ten thousand tons）		Discrete uniform distribution	300	[200,300]
Term of Exploitation（years）		Discrete uniform distribution	25	[20,30]
Ad-valorem Royalty Rates（%）		Discrete uniform distribution	4	[2,8]
Annual Operating Cost（Million dollars）		Triangular distribution	900	+/-25%
Fixed investment（Million dollars）		Triangular distribution	3100	+/-25%
Metal Grade	Manganese	Triangular distribution	27.15%	+/-5%
	Cobalt	Triangular distribution	0.22%	+/-5%
	Nickel	Triangular distribution	1.27%	+/-5%
	Copper	Triangular distribution	1.02%	+/-5%
Metal recovery	Manganese	Triangular distribution	90%	+/-5%
	Cobalt	Triangular distribution	83%	+/-5%
	Nickel	Triangular distribution	87%	+/-5%
	Copper	Triangular distribution	88%	+/-5%

- The proportion of fixed investment loans is 70%
- Interest of 6% in 25 years.
- Taxes is 28%
- Benchmark yield is 15%
- Factory depreciation is 3%,
- equipment depreciation is 7%

2. Determination of model input parameters

Metal price forecast and metal price



Resources Policy 52 (2017) 427–434

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

Forecasting copper prices by decision tree learning

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ARTICLE INFO

Keywords:
Machine learning
Copper prices forecasting
Decision tree
Correlation
Prediction

ABSTRACT

Forecasting the prices of metals is important in many aspects of economics. Metal prices are also vital variables

1. Introduction

Copper price plays vital roles ... miles Li and Li (2015); Sánchez ... McAleer (2004); Gargano and ... copper is strongly associated with ... wiring, construction, and equipm... copper price has become a significa... of related companies and economis... the other hand, for certain develop... extensively on copper production, ... tions in copper price has been plac... it will impact the national incom... Furthermore, copper price provi... market participants such as ban... speculators are active participants ... and McAleer (2004).

Forecasting copper price is par... and participants in the market. F... companies as the payback period... requires a steady and reliable fin... and forecast the future revenue ... flow along the project phase. Rati... financial model is necessary to ... permits to assess the project eve... payment or loyalty from contracts ... land based on the models Garm... directly coupled to the project ...

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http://dx.doi.org/10.1016/j.resourpol.2017.05.007
Received 14 August 2016; Received in revised form 14 May 2017; Accepted 15 May 2017
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Two sets of metal prices were used in the model.

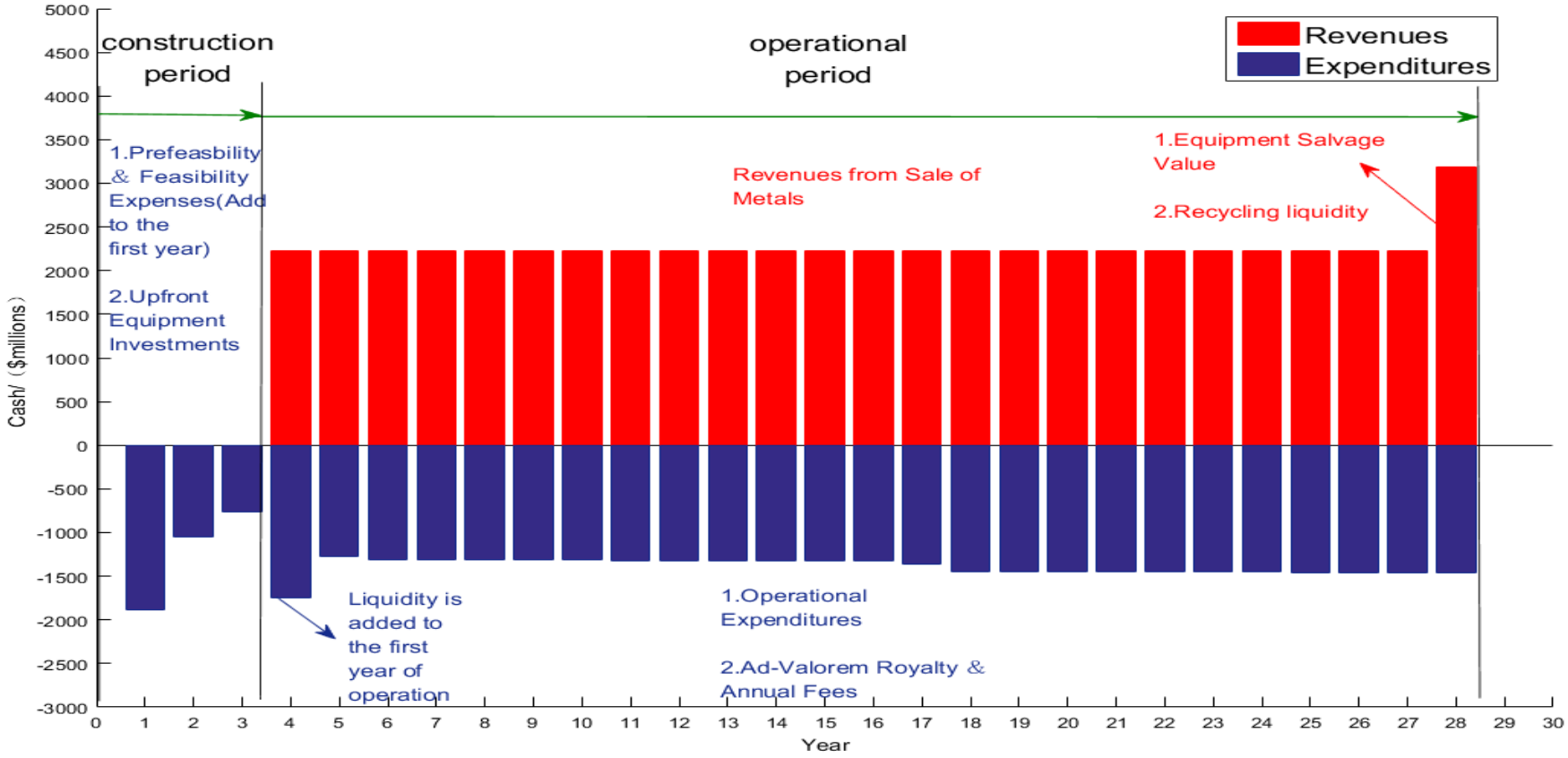
	Expert estimated price ($/ton)	five-year average price ($/ton)
Mn	1685	1780
Ni	12862	12862
Co	64855	33415
Cu	6500	6213

There are many methods for metal price forecasting. We have studied the decision tree machine-learning algorithm based on big data and achieved good results.

Expert estimated price：the metal prices which was submited to ISA in 2017.
The five-year average price was from LME.
The Mn price is from http://hq.smm.cn/meng

2. Determination of model input parameters

Annual parameters input of Discounted Cash Flow Model:



Parameters of the Break Even Point model:

The production cost per ton C is about 600-630 dollars/t, and the break even grades is 4.91% and 4.74%

Ni equivalents of expert estimated price and five-year average price are 5.57% and 5.39%

3. Economic indicators of the project

Results of Discounted Cash Flow Model （basic value）

Metal price	NPV （million dollar）	IRR (%)	Pt (years)
Expert estimated price	465.0	17.12	12.73
Five-year average price	83.8	15.39	20.84

- If 15% is the threshold value of IRR, the exploitation project is economically feasible under the two sets of metal prices.

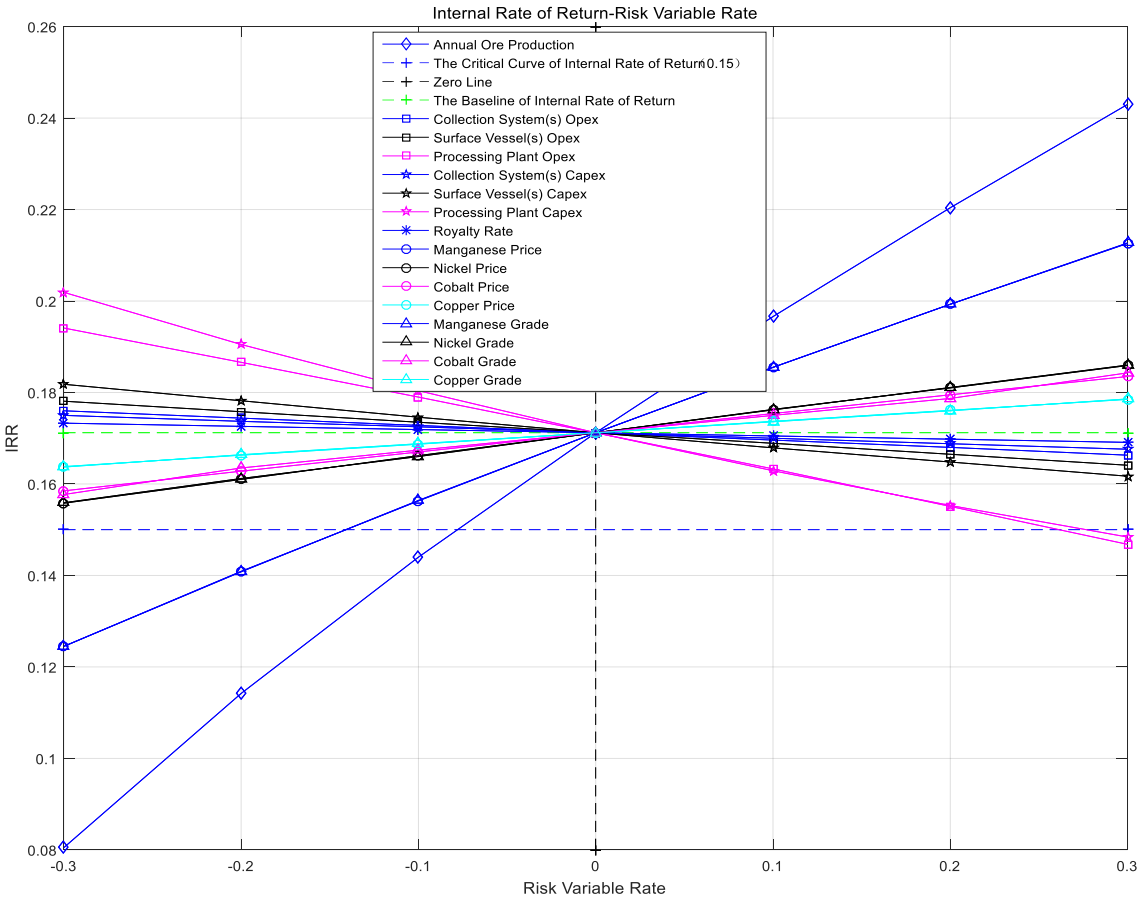
Results of Break Even Point model（basic value）

Expert estimated price	The median of Break Even grade B	4.91%
	Ni Eqv	5.57%
Five-year average price	The median of Break Even grade B	4.74%
	Ni Eqv	5.39%

- B< Ni Eqv under both the expert estimated price and the five-year average price. The exploitation project is economically feasible.

3. Economic indicators of the project

Sensitivity Analysis



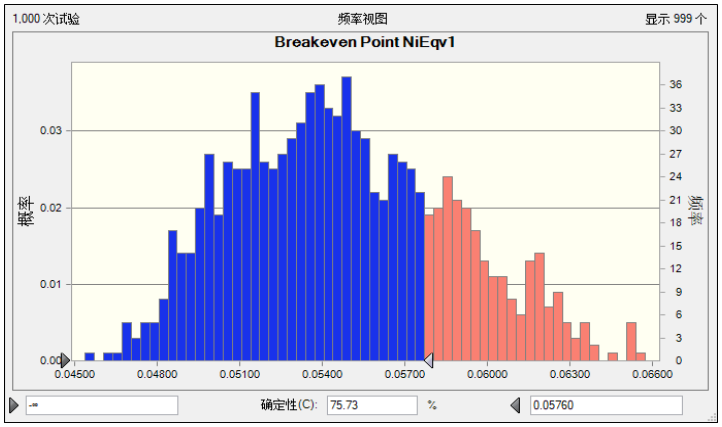
Sorting by Sensitivity	Sensitivity Factor
1	Annual Ore Production
2	Manganese Grade and Price
3	Processing Plant Opex
4	Processing Plant Capex
5	Nickel Grade and Price
6	Cobalt Grade and Price
7	Surface Vessel(s) Capex
8	Copper Grade and Price
9	Surface Vessel(s) Opex
10	Collection System(s) Opex
11	Collection System(s) Capex
12	Royalty Rate

Based on the inputs of expert estimated price, sensitive analysis shows that Annual Ore Production , Manganese Grade and Price , Processing Plant Opex and Processing Plant Capex are major parameters that affect the financial benefit.

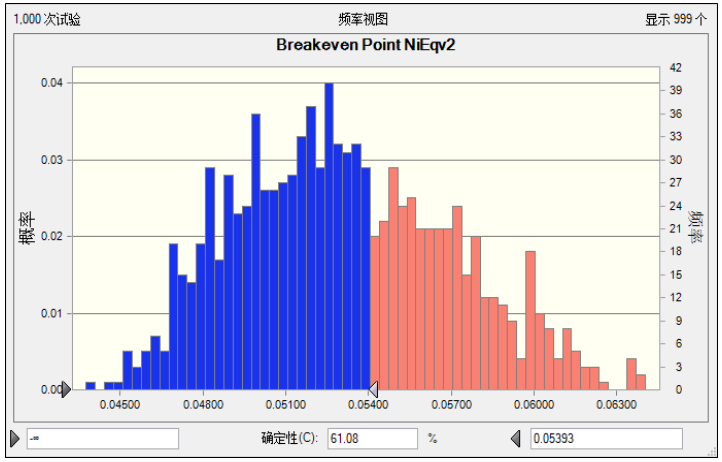
3. Economic indicators of the project

Risk Analysis

Break Even Point Model



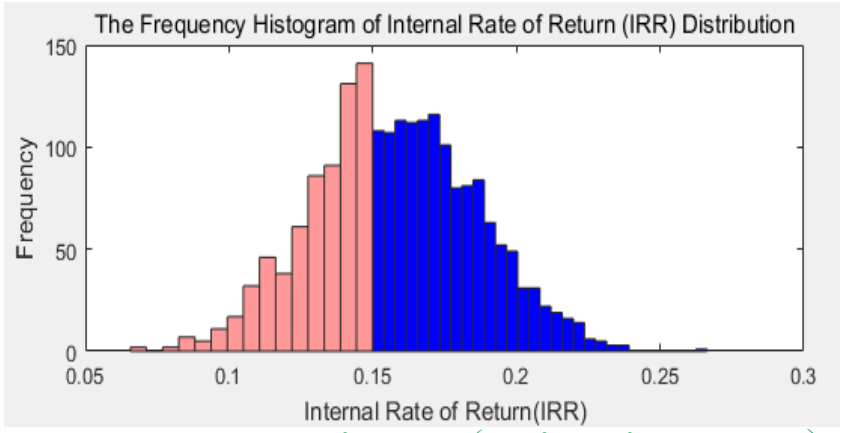
Expert estimated price (risk is about 25%)



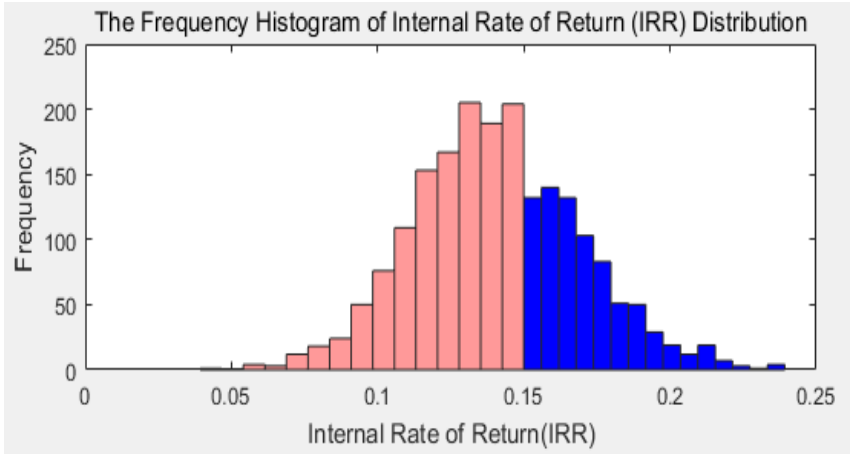
Five-year average price (risk is about 39%)

- Expert estimated price and five-year average metal price used respectively, the frequency distribution of break even grade is shown above.

Discounted Cash Flow Model



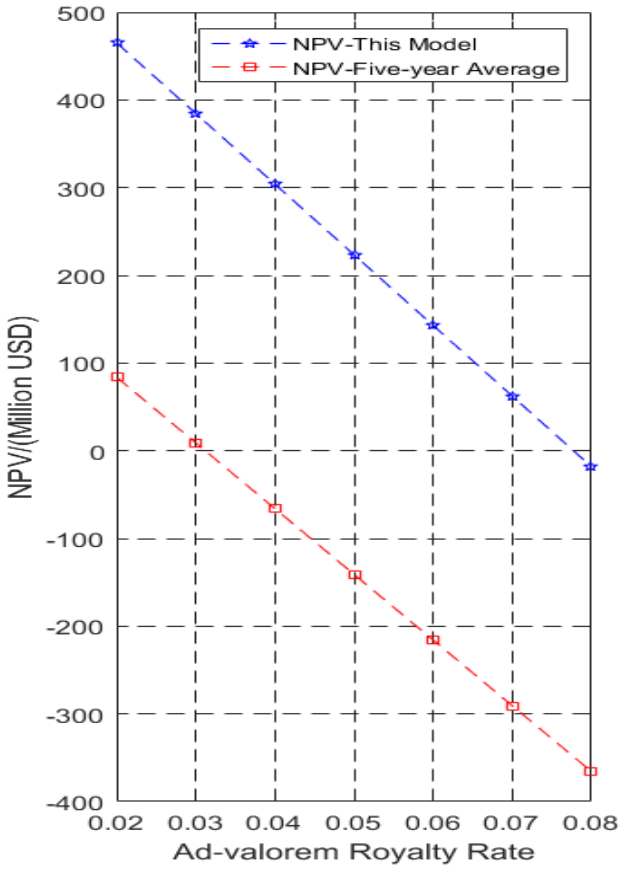
Expert estimated price（ risk is about 35% ）

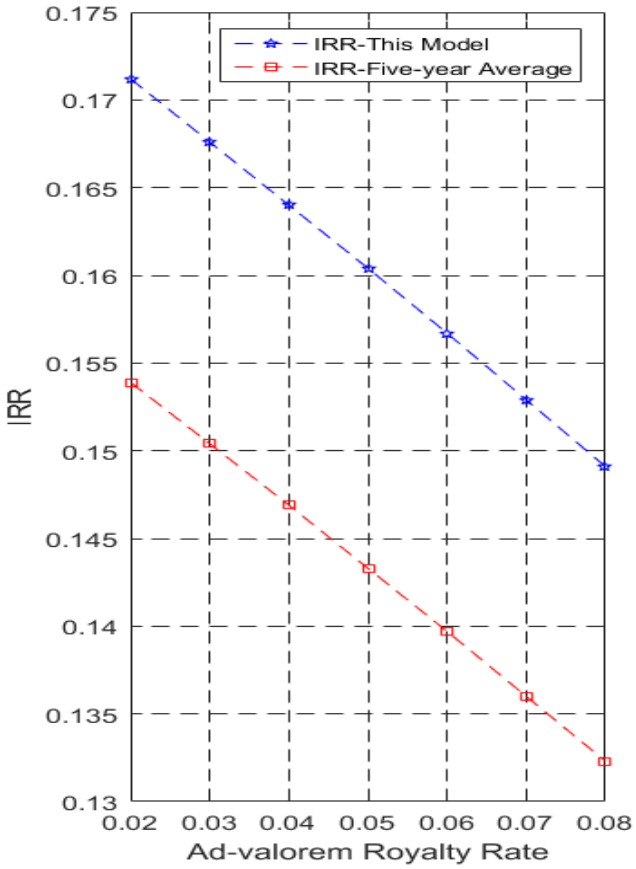


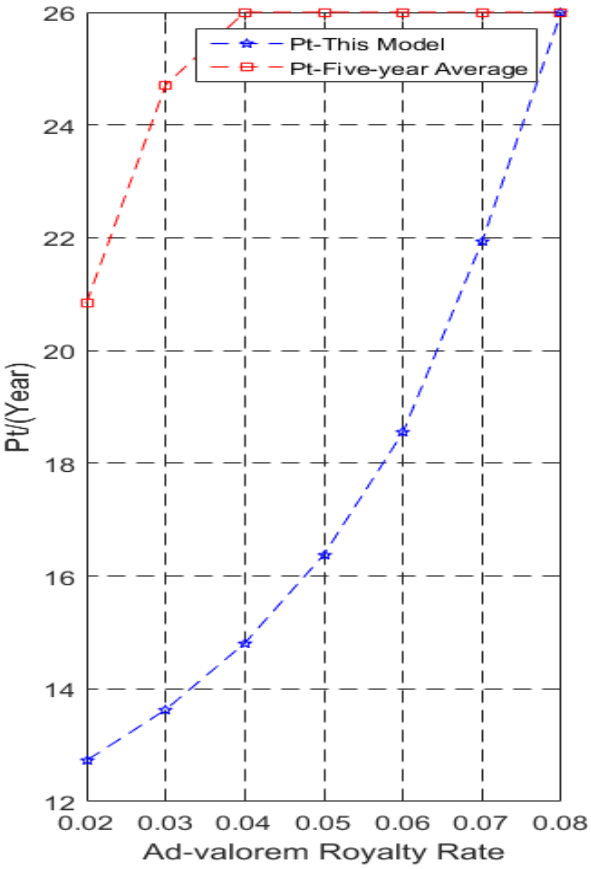
Five-year average price（ risk is about 58%）

- Expert estimated price and five-year average metal price used respectively, the frequency distribution of internal rate of return (IRR) is shown above.

4. Analysis and Comparison of Royalty Rates



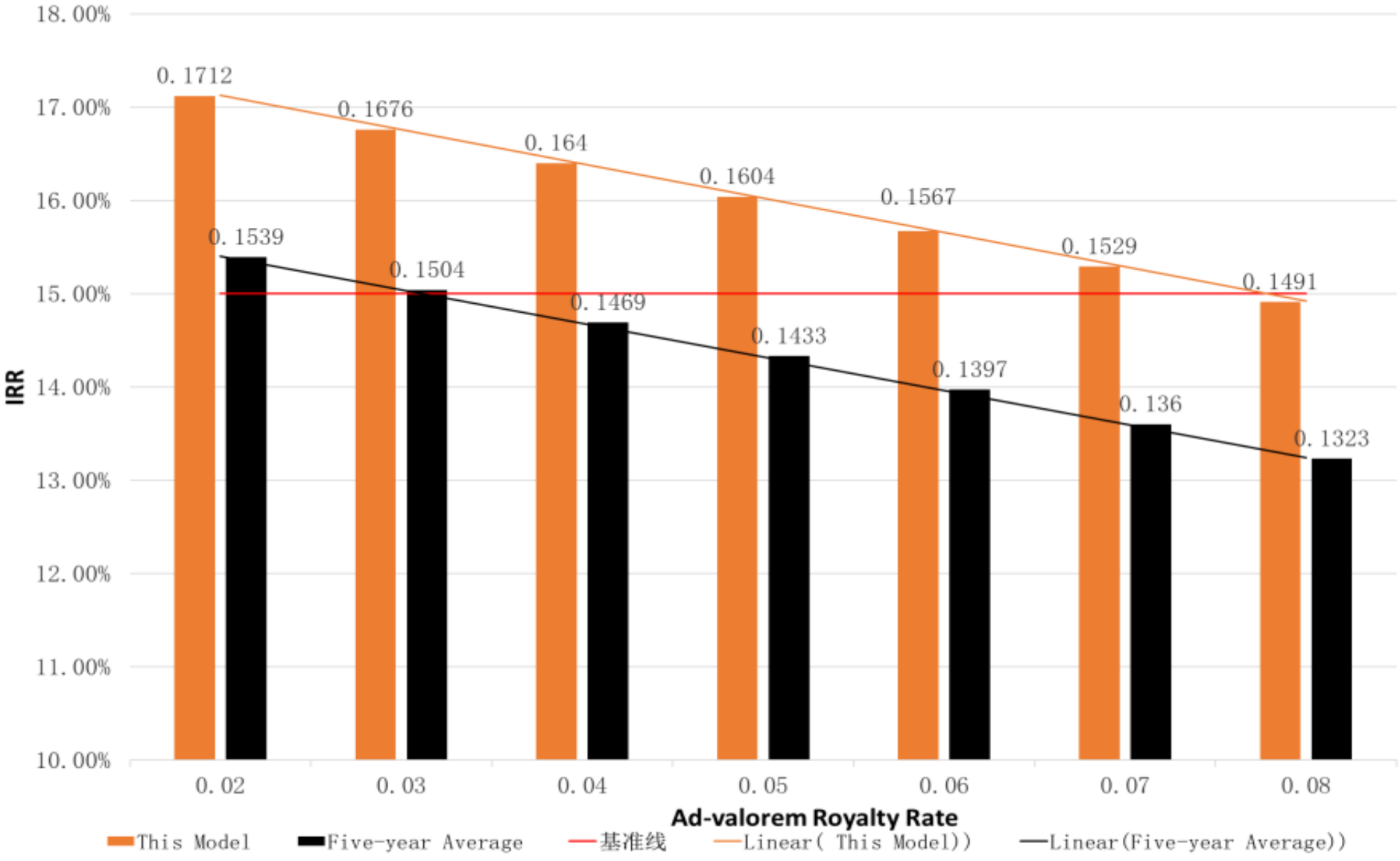




➢When the royalty Rate is equal to 8%, NPV is negative. This shows that the royalty rate has a great impact on the economic evaluation index.

➢According to the average price of metal in the last five years, if the ad-valorem royalty rate is equal to 2%, IRR will fall to 15.39%, and the dynamic investment pay-back period will exceed 17 years. The return of the project is obviously lower than the land mining industry. This is not in line with the principle of "avoid giving deep seabed miners an artificial competitive advantage or imposing on them a competitive disadvantage" proposed by " Implementation Agreement ".

4. Analysis and Comparison of Royalty Rates



Suggestions: if the ad-valorem royalty mode is adopted, the royalty rate should not exceed 2%.

4. Analysis and Comparison of Royalty Rates

"Profit-based +Ad-valorem" Royalty Mode Research

"Implementation Agreement" stipulates that "Consideration should be given to the adoption of a royalty system or a combination of a royalty and profit-sharing system." So we studied "Profit-based + Ad-valorem" Royalty mode.

Using expert estimated price data

Royalty Rate	Ad-valorem + Profit-based			
	2%+0%	1%+3%	1%+4%	1%+5%
IRR（%）	17.12	17.15	17.05	16.94
NPV (Million USD)	465.04	472.86	448.61	424.36
Average annual net present value(Million USD)	16.6	16.9	16.0	15.2
Average annual royalty (Million USD)	50.55	42.44	48.17	53.89

- Considering the average annual royalty and the average annual net present value, the "Ad-valorem 1%+Profit-based 4%" scheme is close to the "Ad-valorem 2%".
- The average annual royalty is much higher than the average annual net present value. This means that the principle of "common inheritance of human property" has been well reflected and implemented.

4. Analysis and Comparison of Royalty Rates

	Incomes	Expert estimated price	Five-year Average price	Relative variation ratio
Ad-valorem 2%	Average annual royalty	50.55	47.01	-7%
	Average annual net present value	16.6	3.0	-81.9%
Ad-valorem 1%+Profit-based 4%	Average annual royalty	48.17	42.77	-11.2%
	Average annual net present value	16.0	2.8	-82.5%

When the prices of metals drop：

• The annual average net present value decreases far more than the annual average royalty, and the contractors take the risk of falling prices.

• By comparing “Ad-valorem” to “Profit-based + Ad-valorem”, the relative variation ratio of average annual royalty increases 4%, and the average annual net present value increases less than 1%. It can appropriately reduce the contractor’s burden under low profit conditions.

Thanks for your attention !