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Comparative Study of Discounted Cash Flow and Energy Return on Investment: Review of Oil and Gas Resource Economic Evaluation

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ABSTRACT

The aim of the paper is to develop a methodology for evaluating oil and gas fields return on investments based on not only finance, but also environmental and social interrelations. The subject of the study is a comparison of methods for calculating return on investments on the example of China, Canada and Russia's oil and gas companies. The authors used a comparative method of calculations, as well as a case study – a comparison of return on investments methods on the example of oil and gas enterprises. In the paper, the authors analyze the next traditional methods of economic assessment: net present value, differential rent, reserve and multiple costs. The authors suggest using a new assessment method that determines the energy return on investment (EROI). This method does not rely on traditional analysis of net present value (NPV), internal rate of return (IRR), and financial sensitivity. It comprehensively takes into account the costs of energy production, environmental protection and energy efficiency. Based on the results of the study, the authors conclude that the advantages of various methods of economic assessment should be integrated in order to avoid disadvantages and create a new dynamic integrated system of economic assessment. Oil and gas companies may use the results of the study to implement the energy return on investment methodology concerning oil and gas fields' evaluation. A promising direction for further research may be to compare the energy return on investment at oil and gas enterprises in different countries as well as developing corporate reporting concerning energy return on investment improving efficiency.

Keywords: Economic evaluation; Net Present Value (NPV); Energy Return on Investments (EROI)

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Сравнение методик дисконтированного денежного потока и энергетической рентабельности инвестиций (EROI): обзор экономических оценок нефтегазовых ресурсов

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АННОТАЦИЯ

Цель статьи – развитие методологии оценки рентабельности инвестиций в месторождения нефти и газа на основе не только финансовых, но и экологических, и социальных взаимосвязей. **Предметом** исследования является сравнение способов расчета рентабельности инвестиций на примере нефтегазовых предприятий Китая, Канады и России. Авторы использовали сравнительный метод расчетов, а также case-study – сравнение оценок инвестиций на при-

мере нефтегазовых предприятий. Проанализированы традиционные методы экономической оценки: чистой приведенной стоимости, дифференциальной ренты, резервных и множественных затрат. Авторы предлагают использовать новый метод экономической оценки, определяющий энергетическую рентабельность инвестиций (EROI). Этот метод не опирается на традиционный анализ чистой приведенной стоимости (NPV), внутренней нормы доходности (IRR) и финансовой чувствительности. Он всесторонне учитывает затраты на выпуск энергии, экологическую безопасность и энергоэффективность. По результатам исследования авторы делают **вывод**, что преимущества различных методов экономической оценки должны быть интегрированы, чтобы избежать недостатков и создать динамичную комплексную систему экономической оценки. Результаты исследования могут быть использованы нефтегазовыми компаниями для внедрения методологии энергетической рентабельности инвестиций на месторождениях. **Перспективным направлением** дальнейшего исследования может быть сравнение энергетической рентабельности инвестиций на нефтегазовых предприятиях разных стран и разработка корпоративной отчетности в направлении повышения эффективности энергетической рентабельности инвестиций.

Ключевые слова: экономическая оценка; чистая приведенная стоимость; энергетическая рентабельность инвестиций (EROI)

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INTRODUCTION

Resources shortage and environmental pollution are the results of industrialization and urbanization of human society. Resource constraints have become a significant obstacle to economic development. Oil and gas are essential strategic resources. Generally, the international oil and gas resources exploration market is increasingly fierce. From a global perspective, the Middle East, West Asia and North Africa are mainly conventional oil and gas resources areas with profound exploration and development costs. North America has a low population density but is rich in oil and gas resources. With the development of technology, the US shale gas revolution has arrived. China has a vast territory, abundant reserves of oil and gas resources and complicated geological conditions. The exploration of oil and gas resources is facing many uncertainties and risks, especially the development of unconventional oil and gas resources. The discounted cash flow method is widely used in conventional oil and gas evaluation methods, especially in the economic evaluation of unconventional energy.

China's shale gas-rich areas are mostly mountainous, with high drilling, fracturing and mining costs. Technology development is still immature. The decline of shale gas wells is very fast, and environmental problems such as carbon emissions, water pollution, and air pollution during the mining process are apparent. The traditional method only evaluates from the perspective of "cash flow", and ignores the environmental factors. Therefore, it is urgent to establish economic evaluation methods and systems for unconventional oil and gas resources [1].

There are some crucial factors in the traditional economic evaluation process, such as the predic-

tion of oil and gas resource reserves, technically recoverable reserves, recoverable economic reserves, the economic exploitation life and the depreciation lifetime. This paper establishes a dynamic economic evaluation system of energy, with emphasis on the EROI evaluation method. The new method no longer relies on traditional NPV, IRR and sensitivity analysis to judge the economic value of oil and gas resources, but comprehensively considers energy input and output, environmental impact and time value (Fig. 1).

THEORETICAL LITERATURE REVIEW OF ECONOMIC EVALUATION METHODS

Resource value assessment has three different methods such as income method, market method and cost method. The discounted cash flow method (DCF), especially the net present value (NPV) method, determines its value by estimating the present value of future expected returns of oil and gas resources. The parameters in the evaluation process are clear, the results are objective and easy to operate. However, the NPV economic evaluation index is too single, and small parameter changes make the results very different. If the oil prices are low, it is easy to make a lower economic evaluation result [2].

Energy return on investment (EROI) is the ratio of energy output to energy input. It is a physical method to measure resource scarcity. Energy input is generally considered as investment related to human activities. Usually, the calculation process of the economic evaluation of resource development does not include natural resources or primary energy input [3]. In EROI calculation process, primary energy and initial exploration investment are considered. Regarding the consideration of energy input, EROI has more comprehensively measured the input and

output factors in resource development from the perspective of biophysical economics. EROI has is considered to be a valuable economic evaluation tool and method that can be widely applied, reflecting energy quality and benefits such as environmental, economic, and social benefits [4].

Therefore, it is necessary to establish a dynamic economic evaluation system for oil and gas resources exploration and to evaluate the input and output from a comprehensively perspective in order to make investment decisions more accurately.

Professor Charles Hall from The State University of New York, quantified the EROI value of energy exploration and found the relationship between EROI value and resource price and economy. He points out when EROI decreases, resource price rises. In other words, lower EROI value means higher resource input cost. Carey King, a researcher in the Energy Research Institute of Austin, Texas, studied the relationship between the net energy decline and economy of dynamic connection of development [4–7].

METHODOLOGY

Net present value method

The net present value method is one type of discounted cash flow (DCF) that is derived from Irving Fisher’s capital value theory. In 1906, Fisher published “The Nature of Capital and Income”, mentioned that capitalizing future income means discounting future income. In 1930, Fisher created a discounted model of future returns, so the net present value formula is as follows [8]:

$$NPV = \sum_{t=0}^n \frac{(CI - CO)_t}{(1+i)^t}, \tag{1}$$

among them:

NPV – Economic benefits of oil and gas resource target areas during the evaluation period;

CI – Cash inflows to developing oil and gas resources during the evaluation period;

CO – Cash outflow for developing oil and gas resources during the evaluation period;

T – Evaluation period, *t* = 1, 2, ..., 30 years;

I – Benchmark discount rate;

$(1+i)^{-t}$ – Discount factor in year *t*.

The NPV calculating is the necessary decision-making process for capital expenditures (outflows) in investment decisions. The quality of the economic evaluation is related to the choice of decision-making and implementation. The net present value of an investment in an oil and gas resource project is the

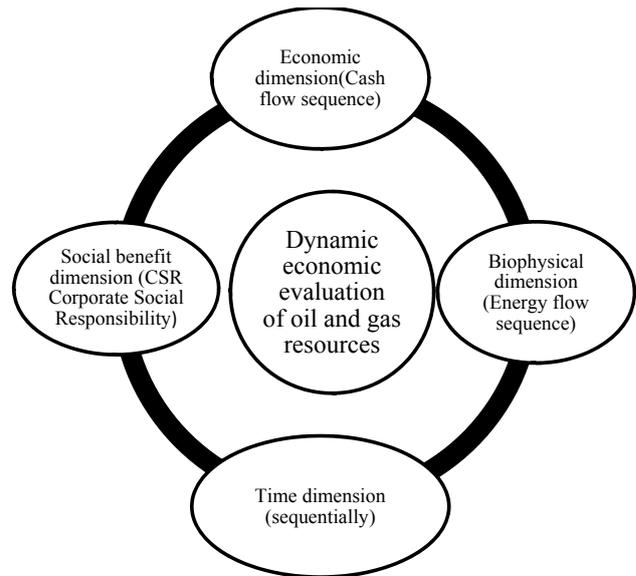


Fig. 1. Framework for the economic evaluation of oil and gas resources

Source: Authors’ methodology.

difference between the present value of the investment project *PV* and the investment cost *C*, which is expressed as:

$$NPV = PV - C, \tag{2}$$

NPV – Economic Benefits of Oil and Gas Resource Target Areas During the Evaluation Period;

PV – Present value (target value) of oil and gas resources;

C – Cost of investment;

Further, refine the method:

$$NPV = -\sum_{t=0}^n \frac{C_t}{(1+i)^t} + \sum_{t=1}^{k+} \frac{C'_t}{(1+i)^t}, \tag{3}$$

*C'*_{*t*} – Expected cash flow for year *t*;

*C*_{*t*} – Investment cost in year *t*;

t – Investment payback period;

i – Discount coefficient.

If the NPV is positive, the project is accepted. Otherwise, the project is rejected. Oil and gas field investment is a large investment project, and it is necessary to estimate the capital investment of current and subsequent periods. In practice, it is complicated to estimate the cash flow of the project in each period of cash flow. Therefore, the average cash flow is generally used. The cash flow for each year is affected by the depreciation rate. The key issue is to determine the discount rate. The more significant the depreciation, the smaller the year-end profit, and leads to the higher the cash flow. Conversely,

the smaller the depreciation, the higher the profit, and the smaller the cash flow. The internal discount rate is called the internal rate of return and refers to the discount rate when the net present value is equal to zero. Regarding the determination of the discount rate, it is believed that the discount rate for conventional oil and gas is 12%, and that for unconventional oil and gas is about 8%. Shale gas is as low as 3% to 4% [9].

NPV and rate of return are two critical indicators of the operating ability of oil and gas companies. The rate of return is the income obtained by the unit invested in capital, and is an essential indicator of corporate profitability. The internal rate of return, IRR, is the discount rate when NPV is equal to zero. In the oil and gas industry investment analysis, the internal rate of return is a vital indicator.

Evaluation of Net Present Value Method

The NPV is based on the present value, and it depends on the cash inflow and outflow of financial data to analyze the opportunity cost, which has absolute objectivity. NPV is additive, intuitive and straightforward. The NPV method also has disadvantages: it is mainly difficult to estimate the discount rate in practice. The DCF model implicitly assumes that there is a static expected cash flow for the investment project, ignoring the value of growth opportunities. Hodder and Riggs summarized three shortcomings of DCF. First, the impact of inflation cannot be handled well, especially in long-term investment decisions. The second is that a single discount rate cannot reflect complex risk conditions. The third is that investment decisions are not only irreversible, but are flexible. Decision-makers can further modify the investment decision based on changes in the external environment and the uncertainty of investment projects to flexible investment to avoid losses [10].

In practice, many projects where the NPV is positive will be reversed during implementation. Taking the Canadian Oil Sands acquisition as an example, the economic evaluation results were made against the background of a high oil price economy, and the acquisition failed in failure. The root cause is a misprediction of cash flow. Therefore, the economic evaluation cannot be based on accepting the project as long as the NPV is greater than zero. Instead, it should look for the economic life of the oil and gas project. In the context of the global financial crisis, oil prices have continued to decline. Also, the evaluation method does not take into account the externalities generated in the production pro-

cess, such as environmental issues, social benefits, employment.

Case study

The factors affecting the NPV include the impact of changes in oil prices and costs on the NPV of investment income. The influencing factors on economic evaluation of tight gas include natural gas price, cost, the life cycle of exploration and development, and discount rate (*Table 1, 2*). Taking tight gas fields in southern China as an example, the annual gas production is 200,000 cubic meters per year of every well, and the expected production period is twenty years.

According to *table 2*, the change of gas price has a great influence on NPV results. In daily practice, the influence of market factors and domestic and foreign political factors on the results of economic evaluation is very important.

Overview of the Energy Return Method EROI Method

Meaning of EROI

As early as 1955, Fred proposed the concept of energy surplus (net energy production), which became the earliest prototype of the energy return on investment (EROI). In 1973, American ecologist Odum first proposed the concept of net energy, which was recognized and cited in the Federal Non-Nuclear Energy Research and Development Act. In 1975, Gilliland published a paper in *Science*, pointing out the superiority of the EROI method and pointing out that it is one of the most suitable methods for evaluating net energy. In 1984, *Science* published Cleveland's article, which put forward the concept of EROI and explained the critical value and significance of EROI for social development and economic growth. However, there is no attention has been paid in the following twenty years [11]. Until 2000, with the outbreak of the financial crisis, sharp fluctuations in international oil prices, and constant changes in the international oil market, American scholar Charles A. S. Hall studied the EROI thresholds of oil and gas resources worldwide.

The EROI method focuses on the following issues: First, the boundary issues of the analysis; second, the correlation of energy quality; third, the mutual transformation of the energy economy; fourth, the EROI threshold database [6, 12]*.

The energy return on investment is the ratio of the output and input of energy development. The formula is shown in (4),

* CGMA. Global management accounting principles. No. May, 2014.

Table 1

$$EROI = \frac{\sum_{i=1}^n E_i^O}{\sum_{i=1}^n E_i^I} \quad (4)$$

Where E_i^O and E_i^I represent the output and input values of the i -th energy respectively.

The above formula shows that the energy cost of low EROI value is far greater than that of high EROI value.

Advantages and disadvantages of EROI evaluation methods

EROI is a new indicator for the economic evaluation of energy investment. With heat value as a unit of measurement, it can intuitively compare the value of different energy production values, effectively evaluate changes in energy quality, and objectively explain the relationship between energy exhaustion and technological progress. Traditional NPV evaluates from an economic perspective, paying attention to the production, cost, and quality of resources using cash flow and profit margins as the basis for evaluation, measuring economic value in terms of currency, and ignoring energy in the process of energy production and conversion consume. EROI method not only considers input and output, but focuses on energy consumption and environmental indicators from the dynamic perspective of energy flow (“material flow”), effectively measures energy efficiency and quality, better evaluates the actual value of energy production, and can adequately explain impact of technological progress on energy output [4, 13, 14].

EROI considers the ecological environment and social impact in the process of energy conversion, and directly measures the level of energy costs. EROI method has not been applied on a large scale in practice, only the theoretical method is highly valued in academia. China Petroleum University (Beijing) Feng Lianyong Petroleum research team members reasonably calculated Canadian oil sand EROI value, the research results nominated for the French Eni Prize 2019 [15, 16]. There are also shortcomings such as there is no uniform international standard for the economic boundary of energy output. Considering the direct and indirect inputs in the process of energy conversion, it is not easy to obtain compared with financial data and requires acquisition. Implied material and energy flow is behind a more accurate amount of money. After EROI defines uniform standards and boundaries, it can provide large-scale databases for practical application for governments and industrialized and the public sectors.

The basic data sheet for tight gas development

No.	Parameter value and description	
	Basic Parameter	values
1	Number of wells	32
2	Time of gas production	20 years
3	Tax rate	8%
	Tax	
1	Value added tax rate	5%
2	Urban maintenance and construction fees	1% of value added tax
3	Additional education tax rate	5% of value added tax
4	Resource tax rate	4.8% of value added tax
	Cost	
1	Fixed cost	281 640 million yuan
2	Variable cost	689.77 yuan/10 ³ m ³
	Income	
1	Gas price	1.5 yuan/m ³
2	Commodity rate	82.37%
	Production	
1	Production of Average annual gas	200 000 m ³
2	Production of Economic annual limit t annual output	4.96*10 ⁸ m ³

Source: China National Offshore Oil Corporation (CNOOC) database. URL: <https://www.cnooc.com.cn/> (accessed on 21.03.2020).

Table 2

Calculation results of NPV at different gas prices

Gas well grade	0.75 Yuan / m ³	1.5 Yuan / m ³
NPV	(10 585 619 971.43)	111 548 002 997.60
IRR	-1.73%	8.05%

Source: Authors' methodology.

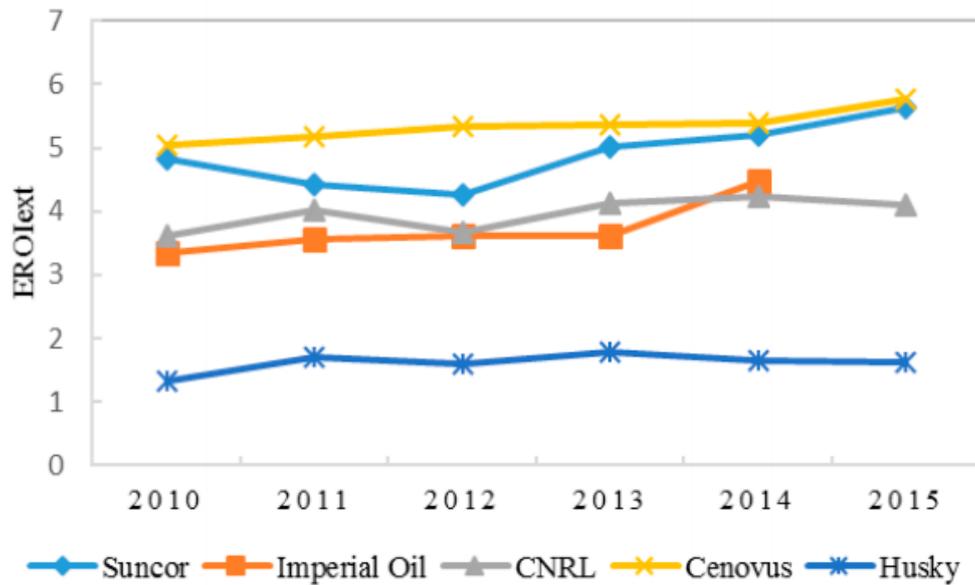


Fig. 2. EROI value of Canadian oil sand company

Source: Disclosing the Facts 2016 [EB/OL]. 2016;11–3. URL: <http://disclosingthefacts.org/> (accessed on 21.03.2020).

Case study of Canadian Oil Sand EROI

Oil sands are unconventional petroleum resources. Because of the considerable pollution during mining and refining, it is also called “dirty oil”. Most of the oil sands resources in the world are concentrated in Canada [16]. The global primary unconventional oil and gas resources currently include heavy oil, oil sands, tight oil, oil shale, shale gas, tight gas, coalbed methane, and so on. Oil sands and shale oil and gas production is currently concentrated only in North America. This research team uses the energy return evaluation method to analyze the value of Canadian Oil Sands resources at the company level from 2010 to 2015. The mined oil sands are transported to a processing plant for separation, and tailing pits are easily generated, and a large amount of fuel is required to separate from oil sands. It can be seen from the figure that Husky’s EROI value is only maintained at about 1, and the investment risk of oil sands projects is very high (Fig. 2).

Study of Russia’s oil and gas potential supply and EROI

Russia is one of the largest energy resource suppliers in the world market. It occupies the leading positions in the world in gas reserves and gas production. According to the Energy Strategy of the Russian Federation until 2030, the country must appoint innovative ways to develop the gas industry and increase its leading position in global energy markets. Nowadays, Russia exports more than 40% of energy resources that obtain 16% in

the world inter-regional trade by energy (Fig. 3). Gas share in Russia’s fuel balance constitutes 62%. However, if we consider only the European part of the Russian Federation, it will reach 86%. The domestic gas industry provides about 10% of national GDP and up to 25% of the income in the country’s budget. There are 755 gas fields in Russia; more than half are already developed or prepared for industrial development. Explored gas reserves across Russia average 15.5%. In the European part of the country it reaches 70%, and in Eastern Siberia – only about 1%. The exploration of potential Russian gas resources is only 24.5%. The gas resources and the sea shelves of the East Siberian and Far Eastern regions are characterized by insufficient indicators of the scale and exploration. This situation indicates excellent opportunities for further expansion and development of Russian gas industry.

Natural gas resources production in Russia is profitable, both economically and in terms of the energy produced. Russian oil and gas companies have improved energy saving and energy efficiency policies. Based on these data, EROI can be calculated. In 2013, the EROI for gas producing, transporting and processing was 79:1 for Public Joint Stock Company (PJSC) Gazprom; 76:1 – for PAO NOVATEK; 116:1 – only for producing – for JSC Yakut Fuel and Energy Company (YATEC). The average EROI of Russian natural gas is calculated as follows (Fig. 4). The growth of energy efficiency as the result of the transversal processes with financial resources affecting the Company’s

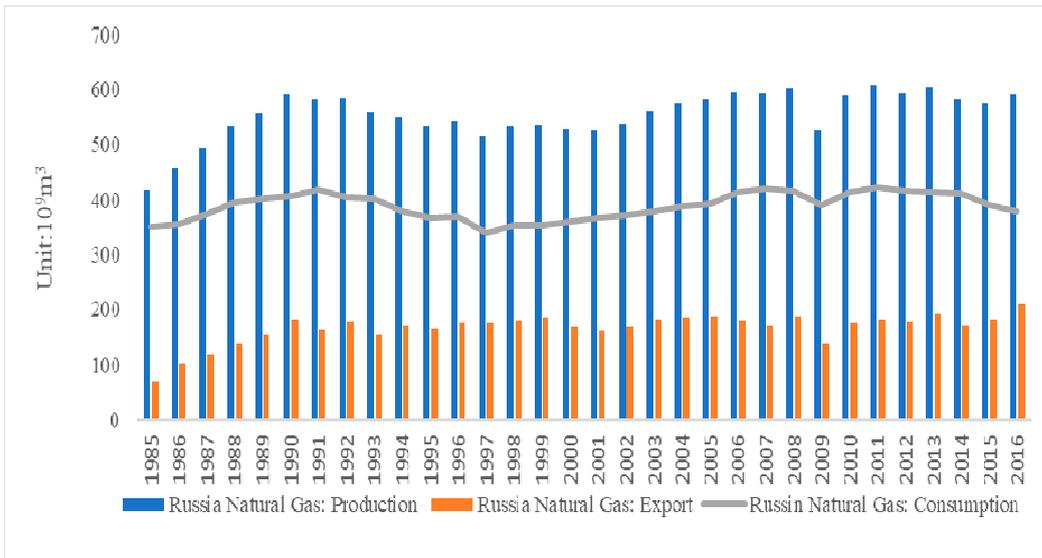


Fig. 3. Russian oil and gas reserves, production and export

Source: BP statistics.

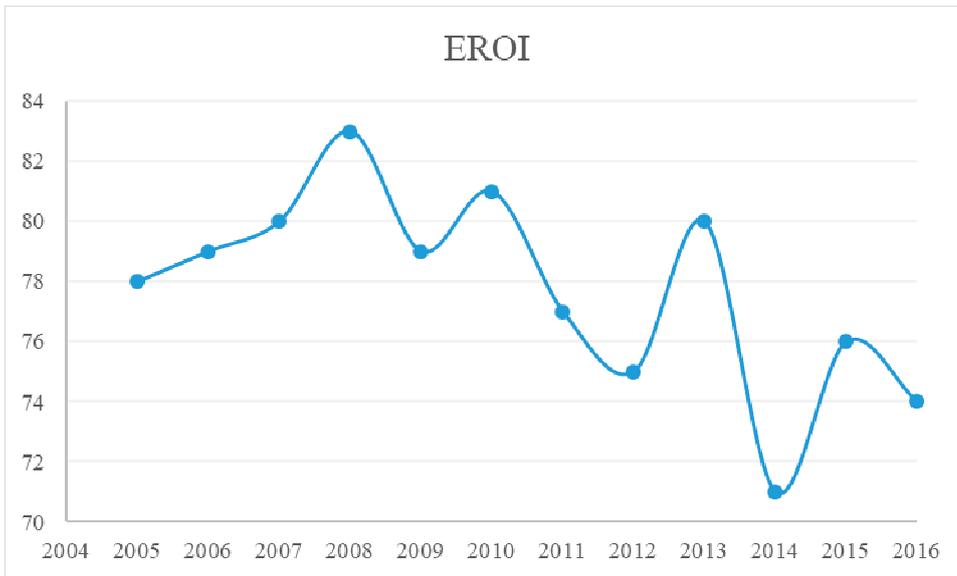


Fig. 4. The average EROI of Russian natural gas

Source: Russian Statistic Agency. URL: http://www.gks.ru/free_doc/new_site/business/prom/en_balans.htm
Annual Report of PJSC Gazprom (accessed on 21.03.2020).

technical innovation state, ecological environment, and social responsibility.

The EROI for oil production in Russia varies in different companies. In 2012, it was in the range of 22–35:1. The EROI for light oil products in 2012 was in the range of 5–13:1. Underestimated cost of fossil fuels leads to distorted economic assessments and investor failure. Incorrect filling out of energy resource data sheets may lead to distortion and deterioration of energy, environmental and technological efficiency indicators, and ultimately to a decrease in internal and external competitiveness.

The relationship between EROI and NPV

The energy return on investment is expressed in units of heat, which is the ratio of energy generation to cost. NPV is a monetary unit that represents a certain value. They may not be necessarily related, but they both are useful indicators of resource economic evaluation (Table 3).

Table 3 shows various NPVs due to gas price volatility. Regardless of how the NPV results change, the EROI for a tight gas field is higher than the standard value.

Table 3

Comprehensive method of economic evaluation

EROI	NPV	Feasibility of oil and gas project investment
EROI higher than reference	NPV > 0, Feasible	Feasible
EROI higher than reference	NPV < 0, Infeasible	Feasible
EROI less than reference	NPV > 0, Feasible	Infeasible
EROI less than reference	NPV < 0, Infeasible	Infeasible

Source: Authors' methodology.

CONCLUSION

The economic evaluation of oil and gas exploration and development includes many internal and external, objective and subjective factors. It is a complex process. The discounted cash flow method is generally regarded as an essential evaluation method, and other evaluation methods, such as a real options method and energy return on investment, are also scientific and practical.

Different assessment methods can make the assessment results very different. Therefore, to establish a scientific dynamic evaluation system it is necessary to comprehensively use different evaluation methods, and consider the exploration and development projects from multiple perspectives of economy, environment, and time. It is particularly essential and necessary to evaluate the exploration and development of resources in all aspects. In the traditional economic evaluation, the net present value method accounts for the perfect proportion and is easy to operate. This evaluation method is based on financial data and has a certain credibility. However, with the development of economy and society and the advancement of science and technology, the traditional single NPV method can no longer meet the needs of investment decisions. People pay more and more attention to the environment, climate change, health. Considering economic factors, this evaluation method will be contrary to objective reality and future expectations. Especially in the context of low oil prices, the evaluation of oil and gas development is often easily underestimated, causing erroneous investment decisions and even waste of resources. On the contrary, in the context of high oil prices, the net present value method will cause blind investment decisions and cause profit losses to the company's future operations. Oil and gas resources are facing challenges and dilemmas on a global scale. Traditional evaluation systems seek to maximize economic benefits and ignore environmental factors. EROI is a newly emerging method for evaluating net energy

output in academia, and its focus is on energy output after deducting energy input. Research on EROI has received much attention in recent years.

There are several methods to evaluate oil and gas resource for investment decisions, a dynamic evaluation mechanism should be established to obtain comprehensive recommendations for investment decisions. Before the calculation of the net present value, the energy return on investment method (think of EROI before money) can be used to comprehensively consider energy costs, quality, and environment to establish a dynamic evaluation mechanism for oil and gas resource investment decisions.

Thus, NPV is a financial and static analysis indicator. Energy Return on investment (EROI) can be regarded from the energy perspective considering energy consumption. When making investment decisions on oil and gas resources, first the project's net present value should be calculated; then, the impact of market prices and cost changes on the economic evaluation results should be measured according to the sensitivity analysis method; then, the option value should be used to modify the net present value. Finally, the EROI value should be calculated and compared to the standard value to comprehensively consider the results of economic evaluation (Table 4).

Both methods have their advantages and disadvantages, and they will not replace each other. Considering these methods in a comprehensive evaluation of exploration and development projects, the results of the evaluation of unconventional projects in the field of oil and gas resources will be more scientific, accurate, and reasonable following the strategic value and significance. Specified non-financial criteria should be used by enterprise valuation evaluation. After the United States imposed sanctions on Russia in 2015, the international situation deteriorated sharply, credit rating went down and financial indicators jumped to the lowest point. Russia's production efficiency management became especially complicated. Quicker assessment

Table 4

Advantages of two methods

NPV	EROI
Simple and easy quantification of financial data	From the perspective of energy flow, input and output are considered comprehensively, which is more accurate

Source: compiled by the authors.

of basic social and environmental responsibility requires developing native methods to correct political bias in credit ratings and sustainability ratings. To evaluate the enterprise, we can use not only the net present value, but also sustainability indicators such as social responsibility indexes, environmental and energy ratings, comparative technologies and other tools. Russia’s objective advantage in the viability of its natural environment was overlooked. The high cost of energy efficiency audits and environmental certifications (for medium-sized companies) aggravated the situation with the assessment of the main success criteria. However, government and companies can use a few tools to improve economic productivity. According to the

paper, the main task is to develop tools to evaluate production energy efficiency by using biophysical economy tools. However, the economists do not pay attention to energy.

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