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Methodology for the Formation of a New Economic Model for Geological Exploration in Subsoil Use

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Abstract: In modern realities, there is no unified methodology for the economic assessment of geological exploration in subsoil use. The main research question of this study was to develop a methodology for the new economic model formation for assessing geological exploration in the subsoil use for the mineral resource base rational use. The new methodology can facilitate the assessment of subsoil users of hydrocarbon reserves and resources and government bodies when putting resources and reserves on the balance sheet. In the course of the study, modeling, observation, description, and analysis methods were used. The result of the study was a new economic model for evaluating geological exploration in subsoil use. The main conclusions can be characterized by the optimization of the main indicators of the valuation of mineral raw materials. The basic principles for calculating discounted cash flow, discount rate, payback period and internal rate of return were developed.

Keywords: methodology, geological exploration, hydrocarbon reserves and resources, modeling methods, cash flow, discount rate, payback period

1. Introduction

In geological study of subsoil, exploration and preliminary assessment, it is customary to define it as a comprehensive study, which contains a number of different assessments, such as geological, technological, environmental, economic indicators. The absence of a unified model for evaluating geological exploration in subsoil use leads to contradictions in the correctness of the result obtained for assessing the efficiency of the use of subsoil and mineral resources. In recent years, the mineral resource base of Russia and the world has been experiencing a shortage of various types of raw materials; for instance, there are changes in the raw material base of the Russian gas industry (Abramov et al. 2018). All this may lead in the future to a profound transformation of the country's economy. The most obvious reason for the occurrence lies in the relative uncertainty of the results when calculating reserves, a sufficiently long term of development of deposits, the presence of its own specific life cycle, and a high capital intensity of production. The result may be the uncertainty of the resulting geological and economic estimates. From the point of view of fundamental science, there is a need for a unified economic model for evaluating geological exploration work, which will regulate the system for evaluating the geological and economic indicators of the geological exploration process, providing for calculating the effectiveness of geological exploration work in Russia at all stages and stages aimed at increasing the validity of management decisions when choosing objects of geological exploration. Consequently, the scientific task within the framework of the research topic is the creation of a new methodology for the transformation of the most important branch of the national economy. The relevance from the point of view of fundamental science is that there is a need for a unified economic model for evaluating geological exploration, which will regulate the system for evaluating the geological and economic indicators of the exploration process, which provides for calculating the effectiveness of exploration in Russia and the world at all stages and stages, aimed at increasing the validity of management decisions when selecting objects for geological exploration.

The current state of research in the field of methodology and modeling of economic efficiency was presented by Trofimov et al. (2017); their position is based on the study of the discounting method and financing of work from their own funds. The study will focus on the application of a unified methodology for evaluating geological exploration in order to select the most effective areas and targets for exploration and rational distribution of financial resources. A significant part of researchers is limited to the presentation of quantitative estimates of efficiency and forecasting (Abrikosov & Beilin 1983). Also, a number of authors considered the geological and economic indicators used in assessing the effectiveness of geological exploration work on the example of an oil field and gave methods of their calculation and application features on the example of a field (Ampilov & Lapo 2010). There are a number of developments and hypotheses aimed at comparing the methodology of using integral indicators of the economic efficiency of projects for the development of hydrocarbon reserves in the formation of a resource base in the planned and market economies of Russia (Anashkin & Rokhlin 2015). The question of the correct determination of the economic efficiency of geological exploration, despite its obvious importance and relevance, has not been finally resolved. In production practice, for this purpose, the value of costs per unit of explored reserves of mineral raw materials is used, that is, the cost of exploration for a unit of reserves. Bochkarev and Pashkevich (1973) tried to define the economic efficiency of exploration. It should be noted that the literature reflects two types of approach to the economics of geological exploration from the point of view of state influence on this category of work and autonomous participation in exploration (Brenner 1979). In the literature, there are two approaches that are aimed at assessing the effectiveness of exploration work. The first approach is due to the development of the mineral resource base of the complex of Russia to ensure energy security and determine approaches to risk assessment (Vasiliev et al. 2015). The second approach is aimed at ensuring rational subsoil use, covering various aspects of the management of the mineral resource complex (Volovich 2013). Authors such as Haldar (2018), Evseenko (2018), Mikhalchuk (2020) conducted research in the field of sources of financing for geological exploration (Sharf et al. 2016).

Other researches are based on the application of the principle of discounting cash flows in assessing the effectiveness of exploration work, from which follows the calculation of the net discounted profit (Novoselov et al. 2014), the internal rate of return and the return-on-investment index (Novoselov et al. 2014, Melekhin & Afonina 2018).

The purpose of the study is to develop a methodology for the formation of a new economic model for evaluating geological exploration in subsoil use for the rational use of the mineral resource base and the development of the national economy of Russia and the world.

The tasks for the realization of the research goal are as follows:

- consider the problems of valuation of the extraction of minerals;
- to determine the main indicators for evaluating the conduct of geological exploration work in Russia and the world, such as net discounted cash flow, discount rates, gross appraised value etc.;
- to find the optimal distribution of indicators of the economic efficiency of geological exploration.

2. Materials and methods

Thus, in modern studies, there are practically no materials related to the role of methodological aspects of assessing the economic efficiency of geological exploration. There are no uniform criteria for evaluating the effectiveness of exploration work for making managerial decisions in the implementation of projects for the development of hydrocarbon deposits.

I chose modeling as the methodological basis of our research. This approach in the study creates a model for evaluating geological exploration in subsoil use. It is effective for generalizing various objects, processes and phenomena for effective subsoil use. This model is aimed at imitating a real economic process, which will reduce labor costs for making managerial decisions to study the economy (Evseenko 2018). This is also relevant when justifying changes in the structure of the mineral resource base in the context of the transformation of the country's fuel and energy complex under the influence of external and internal factors.

General scientific methods planned for use in research (Kuzina 2020b):

1. Method of observation. It will be used for direct observation of changes in the structure of the mineral resource base and indicators of the fuel and energy complex in order to further apply deeper methods corresponding to the objectives of the study.
2. Description method. It is a system of procedures for collecting, primary analysis and presentation of data and their characteristics. In our study, it will be used following the observation method, or the data analysis method, in order to summarize the changes in resources and hydrocarbon reserves, occurring at the present time, or in the future.
3. The method of analysis will be used to identify and study the individual stages of the process of forming a model for balancing subsoil use.
4. Application of the induction method as a process of logical inference based on the transition from a particular position to a general one will make it possible to form a unified model for assessing the market of means of production for field development. This will allow the development of unified algorithms for calculating indicators of the effectiveness of geological exploration.
5. The forecasting method in our study will imply a special scientific study of specific prospects for the further development of the region in which geological exploration is being carried out to assess the environment of the geological exploration object.

3. Results and discussion

The economic assessment of the exploration work is important for the initial stage. At the same time, the methodology for creating a new economic model for geological exploration, according to the author, is based on the following stages:

- preparation of the geological base, while in the author's opinion it is necessary to use the classification of the Society of Petroleum Engineers (SPE), the classification of the American Association of Petroleum Geologists (AAPG) (Hodler & Bhattacharyya 2014);
- conducting an integrated assessment of hydrocarbon reserves and resources, while using the potential income from the use of predicted resources;
- bringing the economic assessment of geological exploration works on the basis of discounting. This method was chosen by the author, because on the basis of the net discounted value (NPV), decisions are made to continue or refuse work or to adjust the parameters of the project for assessing hydrocarbons in the field.

To draw up an economic model, it is necessary to be determined in the composition of the cost estimates of mineral deposits (CEMD) (Emelyanova & Poroskun 2016).

The main purpose of the valuation of mineral resources and subsoil plots is to determine the commercial benefits from their industrial development. The indicator of such a valuation is considered being the net discounted value (NPV) taken into account to determine the effectiveness and feasibility of implementing the developed investment projects related to the development of minerals. The development of investment projects according to the current standards and methods is a very laborious and expensive process that requires taking into account a variety of input indicators and calculation factors and the use of special computer programs. The use of the NPV indicator in the economic assessment was chosen due to the fact that on the basis of modeling cash flows, including all cash receipts and expenses associated with prospecting, exploration and development of a predicted or discovered hydrocarbon field.

The problem of adequately assessing the attractiveness of any investment project associated with raising capital is to determine how much future receipts (or savings) justify today's costs (Voskresenskaya 2019). Therefore, when performing long-term financial calculations, such as a business plan or an investment project, there is no doubt that it is necessary to take into account the changing nature of the cost of monetary resources (Mikhalchuk 2020). Therefore, it is necessary to clearly understand the logic of calculating or choosing the discount rate and clearly interpret the resulting NPV value.

Let's turn to the formula for calculating NPV.

$$\mathrm{NPV} = \sum_{t=1}^{N} \frac{CF_t}{(1+i)^t} - I_0 \quad (1)$$

where:
I_0 – initial investment,
CF_t – cash flows in t years,
N – duration of the project (years),
i – discount rate.

In Equation (1), the discount rate is constant over time. Provided that the discount rate during the year can change an arbitrary number of times M at any time j and act for an arbitrary periodΔ, then we get the following value of the annual discount rate (Kuzina 2020a):

$$i_t = \sum_{j=1}^{M} i_j \Delta_j. \quad (2)$$

Substituting the value of the calculated rate i_t from expression (2) instead of the value of the discount rate i into Equation (1), we obtain the refined formula for calculating NPV:

$$\text{NPV} = \sum_{t=1}^{N} \frac{CF_t}{(1+\sum_{j=1}^{M} i_j \Delta_j)^t} - I_0. \qquad (3)$$

Thus, Equation (3) takes into account the possibility of changing the discount rate during various stages of the investment project. To do this, it is enough to set the forecast dynamics of rate changes and the duration of the period in which it will operate.

As the main indicator of such calculations for the objects of preliminary assessment, it is proposed to determine the estimated value of mineral raw materials in the subsoil, equivalent to the proceeds (gross income) from the sale of commercial products, which can potentially be obtained in the process of full development of the evaluated mineral deposit (subsoil plot) (Sharf 2018).

The indicator that determines the estimated cost of mineral raw materials in the subsoil can be used for the rating assessment of subsoil use objects, as well as in cases where analysis, comparison and selection of subsoil use objects is necessary, in particular, when developing licensing programs for subsoil use, when preparing the terms of tenders and auctions, as well as directly in the process of selecting bidders' bids (Sharf & Grinkevich 2016).

The model of economic appraisal of geological exploration works is as follows: an indicator of the appraised value of mineral raw materials in the subsoil is created. The model is based on the commodity value of mineral raw materials in the bowels of a specific subsoil use object and is determined by the Equation (4).

$$S_{val} = M_{priv} * C_{wl} * I_w \qquad (4)$$

where:
S_{val} – gross estimated value of mineral raw materials in the subsoil;
M_{priv} – amount of reserves and (or) predicted resources of the mineral resource of the object of assessment in the subsoil, reduced by their reliability to the amount of reserves of categories A + B + C1;
C_{wl} – average estimated forecast price determined for the Kondratyev cycle;
I_w – end-to-end extraction of the final product from mineral raw materials in unit fractions.

$$M_{priv} = D_0 \times k_1 + D_1 \times k_2 + C_2 \times k_3 \qquad (5)$$

where:
D_0 – prepared resources,
k_1 – confidence factor of category resources D_0,
D_1 – promising resources,

k_2 – confidence factor of category resources D_1,
C_2 – estimated reserves,
k_3 – confidence factor of category reserves C_3.

M_{priv} is calculated using decreasing confidence factors to the amount of reserves with a low degree of exploration and to the amount of predicted resources, depending on the degree of their validity. For specific geometrized objects with a high degree of exploration, predicted resources of low degrees of validity (D2 and D3) (Sharf 2012, Sharf et al. 2016, Sharf 2017) are not included in the calculation. Off-balance reserves, the use of which at the time of assessment is impossible for mining, technical, environmental and technological reasons, are also inappropriate to include in the calculations (Sharf et al. 2016, Sharf et al. 2018). Only those off-balance reserves are included in the calculation, the use of which may become economically feasible as a result of an increase in the price of this type of mineral raw materials. The values of the reliability coefficients are established for groups of fields according to the complexity of their geological structure.

$$P_{wl} = \frac{\sum p_i}{12} \tag{6}$$

where:
P_i – average price for hydrocarbons for a year.

The calculation used a floating discount rate based on changes in the interest rate Federal Reserve System (FED) (Swierzbinski 2013).

So, for example, when producing natural gas, it is worth taking into account the change in well flow rates; the calculations take into account the maximum flow rates and the minimum flow rates, as well as the application of incentives and their absence in relation to income and property tax, as well as preferences for payment of land lease. The calculations were based on the principles of calculating NPV (according to the formula presented above), while various debit rates and changes in the tax environment were assumed. The result of calculations using the model in Excel was Table 1.

Table 1. Distribution of economic efficiency indicators for various scenarios of natural gas production

Indicators / scenario options	Min rates		Max rates	
	no benefits with a constant discount rate	with benefits with a floating discount rate	no benefits with a constant discount rate	with benefits with a floating discount rate
Accumulated cash flow, RUB mln	45,678.33	47,922.12	91,616.52	96,494.15
Net present value (NPV), RUB mln	-5,634.92	9,162.87	6,509.35	14,723.32
Internal rate of return (IRR), %	7.47	12.58	12.59	13.78
Payback period (simple), years	–	11.00	8.00	7.80
Payback period (discounted) (PP), years	–	17.00	15.00	12.00
Return on capital investment index (ID)	0.80	1.26	1.22	1.30

Source: compiled by the author based on the research of Kuzina (2020a)

Taking into account the improvement in the quality and reliability of data even at the stage of development of hydrocarbon fields, Russian projects calculated by the discounted cash flow method (DCF) in 100% of cases have significant deviations from the calculated values. Costs and revenues discounted for a 25-30 year period after 20 years have practically no effect on NPV and internal rate of return (IRR) (Haldar 2018). In addition to the initial data, which are “probabilistic” in nature, discount rates (Dr) have a great influence on the reliability of calculations (Sharf et al. 2016). The conducted studies (Table 2) showed that, depending on the value of the discount rate, the economic estimates of the same object differ by +, - 16.5% of the discount rate adopted in the calculations = 10%.

The need to carry out calculations in Table 2 is that the discount rate in various options shows the change in all indicators of economic efficiency included in the model of economic evaluation of exploration work.

The following results were obtained, according to the hypothesis at the beginning of the work: the main indicators for evaluating the conduct of geological exploration work were determined, such as net discounted cash flow, discount rates, gross appraised value etc. The results obtained can be used for making decisions in the operation of deposits both on the part of the subsoil user and on the part of state bodies.

Table 2. Analytical generalization of the parameters of calculations using the DCF method at various discount rates

Calculation options parameters	Value of indicators		
	IRR	PP	ID
1. calculation at Dr = 5%	14.80	9.8	1.40
2. calculation at Dr = 8%	13.60	10.2	1.36
3. Basic calculation for Dr = 10%	**12.73**	**12.0**	**1.24**
4. calculation at Dr = 12%	12.05	13.2	1.20
5. calculation at Dr = 15%	10.30	14.8	1.18
6. calculation at Dr = 20%	8.60	15.2	1.06

Source: compiled by the author based

Most of the author, whose works I refer to in the introduction, touch upon the problem of assessing the value of a deposit, and not geological exploration for development. These conclusions contradict my point of view, since I believe that, first of all, it is necessary to assess the economic efficiency of geological exploration, and then proceed to the cost estimate of the field.

There are limitations in the assessment of geological exploration work, since all possible risks of a subsoil user making a decision were not taken into account. These contradictions will serve as the basis for my further research.

4. Conclusion

1. An analysis was made of the current state of the literature in the field of methodology and modeling of the economic efficiency of geological exploration in subsoil use.
2. The main methods for the study were considered, the modeling method was chosen, since it is the most optimal when generalizing various objects, processes and phenomena for effective subsoil use.
3. The author has compiled a model of economic evaluation of geological exploration work, which is based on the commodity value of mineral raw materials in the bowels of a particular subsoil use object.
4. The uniqueness of the results lies in the optimization of the main indicators of the valuation of mineral raw materials, the basic principles of calculating the discounted cash flow, discount rate, payback period and internal rate of return are given.

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