Complex Efficiency Assessment of Development of Arctic Oil and Gas Resources in Russia

Mansur H. Gazeev, Natalia A. Volynskaya and Anatoly B. Rybak

The specific nature of the conditions for the implementation of investment projects in the Arctic zone, in particular, the development of hydrocarbon resources (HCR), requires a national economic approach in assessing economic efficiency. This is due to the high capital intensity, the use and creation of special (innovative) materials, machinery and technologies, the lack of production infrastructure in most of the territories, the increased sensitivity of the natural environment of the Arctic zone to man-caused stresses.

An assessment of economic efficiency based on the indicators of commercial efficiency is insufficient and erroneous. The rationale for investment decisions should be based on comprehensive national economic assessments. In terms of content, such an assessment characterizes the expected magnitude of the full national economic effect of the project and possible environmental damage.

An indicator of the combined economic effect (E_C) of the development of the hydrocarbon resources in the Arctic zone is proposed.

Introduction

The high potential of hydrocarbon resources in the Arctic zone of Russia can have a significant impact on the socio-economic development of both the Arctic territories and the country as a whole. The specific character of economic activities in the Arctic areas as well as natural and technological peculiarities of hydrocarbon developments determine their multisectoral and innovative pattern, and simultaneously, an increased level of risks. Implementing Arctic zone resource development programs suggests an active involvement of the state. This requires adequacy of criteria used for the projections and evaluation of economic efficiency. This paper maintains that classical revenue-based methods are insufficient for assessing hydrocarbon development project efficiency in underdeveloped territories, to which the Russian Arctic zone belongs, including oil and gas resources of the Arctic offshore areas. A methodological approach to the formation of an integral criterion of efficiency is proposed. To implement this task in practical terms, the authors developed tools that were used in the calculation of economic efficiency in developing mineral resources on the continental shelf of the Russian Federation's

Mansur H. Gazeev is Professor at Tyumen Industrial University, Tyumen, Russia. Natalia A. Volynskaya is Director of Fuel and Energy Independent Institute, Moscow, Russia. Anatoly B. Rybak is Head of Dept of Fuel and Energy Independent Institute, Moscow, Russia.

Arctic seas. The results of the calculations show that under the proposed criterion the expected efficiency in hydrocarbon developments differs markedly from the same results obtained by traditional methods. These differences are due to effects induced in related sectors of the economy and potential environmental damage. The proposed criterion allows one to explicitly assess the impact of imports substitution on effects in related industries and, consequently, on the total national efficiency of developing hydrocarbon resources in the Arctic zone of Russia.

The subsoil of the Arctic zone of Russia along with other mineral resources has an exceptionally high potential for hydrocarbon resources, which are in the initial stage of their development and geological study. According to various sources, for example (Shpurov, 2017), hydrocarbon resources of the Russian Arctic sector are estimated at 316 billion barrels of oil equivalent (boe), or about 60% of the total potential Arctic hydrocarbon resources, of which 235 billion boe are situated offshore and 81 billion boe onshore. In the process of exploration this value can increase significantly. This means that the state policy in the field of exploration and development of the Arctic hydrocarbon system is an essential factor of Russian socio-economic and scientific-technological development. Over the last years, the state's attention to the Arctic zone as a strategically important territory of the country has increased, in particular a new version of the state program for its development until 2025 has been adopted. In this regard the relevancy of the investment projects economic efficiency predictive assessment grows with a possibly more complete account of the regional specifics conditions and system macroeconomic consequences, which is necessary for determining the strategic development priorities.

Specific Aspects of Operations in Russian Arctic Zone

Currently a significant part of scientific practical research and methodological developments concerning some project economical efficiency assessment suggests the use of traditional investment analysis tools applying, as a rule, income methods based on the modeling of cash flows taking into account inflation, risk and the minimum rate of return. However in substantiating long-term management decisions on such projects as the development of hydrocarbon resources of the Arctic territories of Russia, it is not enough to handle only the estimates of direct commercial effects of their implementation. The specific conditions of such investment projects, as already mentioned, require a broader national economic approach.

The authors assume that the specific aspects of hydrocarbon development in the Arctic zone affecting the efficiency and approaches used to measure it are characterized by the following:

- harsh natural and climatic environments of the Arctic zone cause the increased risks of any economic activity, especially hydrocarbon resource development which is a complex high-tech process further complicated by high geological risks;
- specific requirements to the technologies/materials used in the Arctic zone and operations' seasonal character lead to higher costs of investment projects;
- low density and patchy character of the Arctic zone's economic development increase significantly the cost and time required to fulfill transport, energy, production and social infrastructure projects. For example, population density (Rosstat, 2017) of the Arctic territories of the North-West (0.2 person/km^2) and Ural (0.7 person/ km^2) administrative districts is drastically less than the relevant average numbers for these districts (2.7 person and 9.9 person per km^2, respectively). Development of hydrocarbons in the Yamal-Nenets

Autonomous Okrug has required the construction of the 525 km long railway line Obskaya-Bovanenkovo, with plans for a massive railway development of Yamal (see https://regnum.ru/news/2466759.html);

- relatively poor degree of geological study of the Arctic zone subsoil, which reduces the reliability of existing estimates of the resource base and increases timing, costs and risks of project implementation (Shpurov I.V., 2017);
- increased sensitivity of the Arctic zone natural environment to man-caused stresses, which leads to stronger environmental restrictions and higher cost components of projects, increases the duration of and makes it more technically difficult to carry out emergency/salvage measures and eliminate the consequences in cases of emergency situations;
- a large share (more than 70%) of the Arctic zone hydrocarbon resource potential is located in the offshore areas (Shpurov I.V., 2017). Developing such resources to a considerable degree is of innovative nature and in many cases requires designing special technologies, equipment and materials. The problem is complicated by the lack of accumulated experience in the development of hydrocarbons in the Arctic shelf;
- high scientific content as well as significant percentage of the infrastructure component in the future costs determines the necessity for direct/indirect participation of the government in the Arctic projects. "Scientific content" shall mean – as the authors understand this term – a share of innovations attached or organic to various techniques and methods of hydrocarbon exploration and production, this requiring not only better related industries but also fundamental research and development;
- uncertainty of economic and legal conditions for the realization of investment projects in the Arctic, this precluding any discussion of the cost and revenue allocation between potential project participants.

Obviously, under these conditions, the economic efficiency estimate based on commercial efficiency does not meet the strategic goals that have been set. The justification for investment decisions and priorities should be based on integral national economic assessments. In meaningful terms, such an assessment must characterize the expected scale of the full national economic effect of the project implementation and cover the risks of possible environmental damage.

Comprehensive Criterion for Estimating Project Efficiency

By now, there are no international or Russian techniques for the complex assessment of such projects that would take into account economic, innovative and environmental parameters within a single (financial) space. The innovation aspect acquires special significance for the Russian economy. In this regard, when estimating the effectiveness of innovative projects, a macroeconomic assessment is needed that characterizes the impact of projects on the national and regional economies. The consideration of environmental consequences (damages) in the development of the Arctic seas shelf is hindered by the lack of sufficient operational experience in such areas of the subsoil, which in particular creates problems of insurance for these risks. And, finally, a low level of geological study of the subsoil areas of the regions mentioned above raises the need for solving the problems of methodological and instrumental supply for accounting for the uncertainty in the economic estimate of hydrocarbon reserves and resources.

In general, the expected complex economic effect (E_C) from the subsoil areas development, as it was shown in Gazeev, Rybak and Volynskaya, 2015, should be formed by three components characterizing various aspects of such development's impact on the social and economic system:

- direct aggregated economic effect occurring in the course of the project implementation, which is quantitatively estimated by the sum of the project' cash flow value before taxes (NPV_0), taking into account risks;
- economic effect occurring in the related industries (E_{RI}) in the process of project implementation; and
- cost estimation of the possible ecological damage (D_E).

According to Gazeev M.H., Rybak A.B. and Volynskaya N.A. (2015), the value of complex economic effects can be represented by the formula (1)

$$E_C = NPV_0 + E_{RI} - D_E. \quad (1)$$

Let us consider in more detail how each of the components of the proposed criterion (1) is shaped.

Direct Aggregate Economic Effect

The first component of the complex criterion – direct aggregate economic effect - is measured by the discounted cash flow value (NPV_0) before taxation. At the stage of predictive assessment and strategic priorities identification there is no information on the economic-legal (including tax) regime, sources of financing and forms of state participation in the project implementation. Consequently, the subject of evaluation at this stage is only the amount of potential of the expected cash flow. The evaluation of commercial efficiency indicators is premature and not provided with the necessary information.

As already mentioned above, the value of project cash flow before taxes (NPV_0), should be calculated taking into account risks. The quantitative risk assessment based on statistical methods is hindered due to poor geological study and economic development degree, as a result of which there is a lack of sufficient technical and economic information array. In light of the exceptional variety of risks of different kinds that arise when investing, for example, in geological exploration and operation in the Arctic conditions, the use of simulation methods is often simply impossible.

Therefore, the application of expert estimates based on the results of geological exploration and operational works and investment activities in the oil and gas sector seems to be justified. For this purpose, it is proposed to use the so-called "method of adjusting the discount rates".

Despite the fact that this method does not provide any information on the degree of risk (the value of possible deviations from the design results), it makes it possible to significantly improve the comparison accuracy of the economic efficiency of objects located in different natural-climatic zones and at the different stages of geological study. Such comparative assessments are an indispensable element in the formation of development strategies and ranking of hydrocarbon assets.

Table 1 sets out the values of the indicative risk adjustments to the basic discount rates. Two types of risks are considered: geological and natural-geographic. The premiums are provided for each type of risk.

Table 1 – The proposed risk premiums to the base discount rate (10%) depending on the exploration degree and economic/geographic location of oil and gas fields. Data on water areas are given according to (Nazarov & Kalist, 2006).

Risk measure	Region characteristics	Location		Exploration degree	Risk premium, %		Total discount rate
		Water area	Onshore		geological	natural and geographical	
Medium	New region with poorly developed infrastructure, bordering on developed regions	-	Murmansk and Arkhangelsk regions, North of Komi, Nenets AO, islands in the Arctic Ocean	Reserves $A+B+C_1$	0 – 1	1-2	11-13
				Reserves C_2	2 – 3		13-15
				Resources C_3	4 – 5		15-17
				Resources D	6 - 8		17-20
High	New region with no infrastructure and/or complicated ice situation	Bering, Pechora, Barents, Kara Seas	North of the Republic of Sakha, Taimyr AO, Kamchatka Region, Chukotka AO, Yamalo-Nenets AO	Reserves $A+B+C_1$	0 – 1	3-4	13-15
				Reserves C_2	2 – 3		15-17
				Resources C_3	4 – 5		17-19
				Resources D	6 - 8		19-22
Very high	Unexplored region with no shore infrastructure, with severe ice conditions, requiring special technical solutions to develop hydrocarbons	Seas of the Eastern Arctic	-	Reserves $A+B+C_1$	0 – 1	5-7	15-18
				Reserves C_2	2 – 3		17-20
				Resources C_3	4 – 5		19-22
				Resources D	6 - 8		21-25

Arctic regions are divided into three groups: with medium, high and very high risk measure. In the Arctic conditions the regions with a low risk level are absent. The premiums for geological risk are determined depending on the degree of exploration of deposits and the reliability of their reserves. For example, for commercial $A+B+C_1$ category reserves the minimum premium value is accepted: 0% - 1%, for C_2 category reserves the premium is in the range of 2% - 3%. The maximum value of the premium for geological risk is established for the predicted and prospective D category resources and makes 6% - 8%. The premium for natural and geographical risk is 1% - 2% for regions with medium risk, 3% - 4% for regions with high risk and 5% - 7% for regions with a very high development risk.

In general, the total risk premium can vary from 1% to 15%, and the final discount rate – from 11% to 25%. The given values of discount rates can be used in calculating the income received or lost.

Economic Effect in Related Industries

The hydrocarbon resources development of the regions under consideration along with direct sectoral effects is accompanied by a set of systemic effects, in particular: socio-economic, innovation-technological, ecological, regional and geopolitical. Note that the last of listed effects defy the formalized cost valuation, therefore, the procedure for coordinating investment decisions on this criterion, as a rule, is carried out using expert assessment methods.

As a quantitative measuring instrument of systemic effects, it is proposed to use the predicted value of GDP additional growth, caused by the implementation of the relevant project (multiplier effect), which is formed due to the additional development of related industries and manufactures, the corresponding development of infrastructure and social sphere (E_{RI}). The application of the multipliers theory is based on the results of calculating the promising inter-industry balance.

The multiplier in macroeconomics is a numerical coefficient that shows how many times the final indicators of economic development will change with the growth of investment or production in the analyzed branch of activity. Since in our case, the added value is estimated, the multipliers for added value (GDP growth) are used, which arise in related sectors of the economy per unit of investment in the evaluated projects. The magnitude of the multiplier effect depends on the share of imported products, technologies and services used. A decrease in the share of imports increases the values of the multipliers. With a view to current sanction restrictions on Russia and the maximum import substitution policy pursued by the government, below we give the multiplier values which would reflect a total abandonment of imports. In other words, the following values and results calculated on their basis correspond to the maximum estimate of the multiplicative effect. The multiplier values in the main sectors of the economy are given in Table 2 and are discussed in detail in (Shirov & Yantovskii, 2011).

Table 2 – Estimation of operational multipliers in the most important sectors of economy with no account of imports

Activity type	Multipliers (operational)
Crude oil production	1.35
Natural gas production	1.31
Oil refining	1.88
Ferrous metallurgy	1.65
Machinery and equipment manufacture	1.87
Sea vessels and equipment manufacture	2.20

Railway transport manufacture	2.57
Construction	2.05
Transportation and storage	1.75

The high capital intensity of hydrocarbon resources development in the Arctic territories, and in particular in the shelf areas of the Arctic seas, suggests that the effect in related industries should be evaluated not only at the development stage using the production multiplier but also at the investment stage with an estimation and use of the investment multiplier according to Gazeev M.H., Rybak A.B. and Volynskaya N.A. (2015) by the formula:

$$E_{RI} = (M_{IN} \times \frac{\overline{K}}{\overline{D}} + M_P) \times \Delta\overline{D}, \quad (2)$$

where:

M_{IN} – investment multiplier;

M_P – production multiplier;

$\overline{D}$ – average annual discounted gross revenue from hydrocarbon production;

$\overline{K}$ – total discounted capital investments;

$\Delta\overline{D}$ – growth in the annual discounted gross revenue, which is equal to $\overline{D}$ for new investment projects.

The value of the investment multiplier is calculated by the formula:

$$M_{IN} = \sum_1^P \alpha_i \times M_i , \quad (3)$$

where:

i - number of identified related industries or industrial complexes, i = 1,…, P;

P – number of industrial areas identified within the project's capital costs;

α_i – the share of funds spent on the products of the i-th industry in the structure of project's total capital costs, $\sum_i^P \alpha_i = 1$;

M_i – operational multiplier of the i-th industry.

Due to the fact that the structure of capital costs can vary significantly from one project to another depending on geological, natural and other factors, as well as on the technology for developing the resources of a particular subsoil block, the value of the investment multiplier (M_{IN}) should be determined for each project (block) individually.

Potential Environmental Damage

Let us turn to the issue of quantitative accounting of environmental risks. Securing a zero discharge system during hydrocarbon resource development in the Arctic territories (especially the Arctic shelf) requires the implementation of environmental protection measures in its entirety, including insurance payments. The expenses in all these mentioned areas are included in the total project investment and costs. Nevertheless, there remains the risk of a major accident, which in its consequences can be attributed as an environmental disaster.

It is especially important to take into account the probability and damages of such an accident in the course of development of the shelf resources, since there is not yet any technology which can preclude catastrophic accidents on oil and gas platforms operating in the severe natural conditions of the Arctic shelf. Of course, the probability of an accident like the one that occurred in the Gulf of Mexico is not high, but it cannot be ruled out. Depending on the degree of exploration and economic and geographic location of the oil and gas fields of the continental shelf, it is suggested, by analogy with Table 1, to classify the objects of the hydrocarbon resources development in different water areas according to the degree of ecological risk.

On the basis of the risk assessment presented in the Declaration of Industrial Safety of the Offshore Ice-Resistant Fixed Platform "Prirazlomnaya" coordinated with the Ministry of Emergency Situations of the Russian Federation on 24.08.2009 № F-03/03-203 and Rostechnadzor (Federal Environmental, Industrial and Nuclear Supervision Service) on 25.09.2009 № 07-07/3146, and a number of other sources, the authors carried out an expert assessment of the probability of an environmental disaster occurrence during the development period for different regions. The results of the analysis are shown in Table 3.

For the Arctic territories, the ecological component is a necessary attribute of valuation of any investment project (Strategy for Development of Russian Federation's Arctic Zone and Provision of National Security up to 2020 approved by President of Russia; Federal Law 'On Environmental Protection' of 10.01.2002 № 7-FZ). The damage caused by environmental pollution is taken into account when making management decisions on any level, especially in view of the commitment by the oil companies to compensate for all the costs incurred in neutralizing the spill consequences which can be enormous in case of the territories under consideration. It is enough to quote the figures in connection with the explosion on the BP oil platform in the Gulf of Mexico in April 2010. The company only managed to stop the oil spill on August 4, 2010. The accident resulted in about 5 million barrels of crude oil spilled over. According to Neft I Kapital (Oil and Capital) e-edition (2013-1) and (2013-2), BP agreed to pay out compensation for the damage caused by the accident in the amount of 42 billion USD, while the total losses exceed 90 billion USD together with additional claims from several states.

Despite the high damage estimates from the accident described above, ecological damage will be much higher in the Arctic shelf environment. First of all, it is technically extremely difficult to ensure a sufficiently complete oil spillage recovery in ice conditions, besides the natural mechanisms of oil residues decomposition do not work in the Arctic latitudes.

Table 3 – Ecological risks classification in relation to economic and geographical location of oil and gas fields

Risk degree	Region characteristics	Location		Probability of major accident, %	Duration of accident, days
		Water area	Onshore		

Medium	New region with poorly developed infrastructure, bordering on developed regions	-	Murmansk and Arkhangelsk regions, North of Komi, Nenets AO, islands in the Arctic Ocean	2 - 3	20 - 60
High	New region with no infrastructure and/or complicated ice situation	Bering, Pechora, Barents, Kara Seas	North of the Republic of Sakha, Taimyr AO, Kamchatka Region, Chukotka AO, Yamal-Nenets AO	4 - 7	60 – 150
Very high	Unexplored region with no shore infrastructure, severe ice conditions, requiring special technical solutions to develop hydrocarbon resources	Seas of the Eastern Arctic	-	8 - 10	150 – 180

In the first approximation the value of ecological damage (D_E) can be estimated from the formula:

$$D_E = k_E \times \bar{q} \times t, \quad (4)$$

where:

k_E – damage (penalty) from a spill of 1 ton of oil,

$k_E = k_u \times p_u$

k_u – unit economic damage from the spill of 1 ton of oil;

p_u – probability of a major accident (oil spill);

$\bar{q}$ – daily oil spill, t/day,

t – duration of the accident, days.

The value of the specific ecological damage from the spill of 1 ton of oil (k_u), taking into account the available actual data, is estimated by us at 60,000 USD per 1 ton of spilled oil in case of an accident on the continental shelf and 6,000 USD in case of an accident onshore. The remaining parameters are random values. A quantitative assessment of the probable ecological damage resulting from a major accident for each project can be obtained using simulation methods, in particular the Monte Carlo method. It should be noted that depending on the location of the subsoil area, the probability of a major accident can vary from 2-3% for regions with a medium development risk, up to 8-10% for regions with low exploration level and severe ice conditions (very high development risk). Accordingly, the duration of the accident can vary from 20 days to six months. Note that the category of medium development risk does not include any of the Arctic water areas.

Conclusions

Based on the accumulated technical and economic information on subsoil blocks containing hydrocarbon resources and located in different water areas of the Russian Federation Arctic shelf, the authors carried out a large amount of experimental calculations to determine the values of traditional (income-based) and proposed (complex) efficiency criteria of their development. The results of these calculations presented in Table 4 showed an exceptionally high influence of the conjugate effects on the estimates obtained. In addition, not only the values of the efficiency indicator change, but so do the preferences for specific subsoil areas of development. Moreover, taking into account the conjugate effects in a number of cases changes the economic priority of development of the water areas as a whole. Note that for the comparability of obtained results, for each water area average estimates are given for hydrocarbon resources of same groups of exploration level.

It is necessary to stress once again that the estimates presented in Table 4 are obtained from the hypothesis that all imports have been substituted in full in related industries, thus maximizing the value of multipliers, effects in related industries, and consequently, integral economic effect. More imports of technology, equipment, materials, etc. will reduce the multiplier effect. Respectively, the share of possible environmental damage will become higher in the structure of an integrated criterion.

Table 4 – Results of calculating economic efficiency of developing the Arctic seas continental shelf prospective structures

Water areas	Direct aggregate effect (NPV_0) (traditional criterion)	Multiplicative effect in related industries	Probable ecological damage	Complex economic effect
	USD/bbl			
Pechora Sea	42.1	28.8	2.1	68.7
Laptev Sea	0.3	40.0	7.1	33.2
Bering Sea	-1.7	41.6	16.1	23.8
Kara Sea	3.1	22.6	3.5	22.2
Barents Sea (north)	10.0	6.7	4.2	12.5
Barents Sea (south-west)	10.9	5.9	6.3	10.4

The calculations were carried out under the following assumptions:

- price of crude oil 70 USD per barrel;
- exchange rate 60 RUB / USD;
- average values of the discount rate from Table 1 were used for the relevant water area and exploration-degree;
- ecological damage was estimated using the data contained in Table 3.

From the analysis of the data in Table 4, it follows that with regard to the criterion of direct economic efficiency (NPV_0) the development of the Arctic offshore areas in the Laptev Sea, Bering Sea and Kara Sea is least effective. Furthermore, the development of hydrocarbon resources of the Bering Sea shelf is wholly uneconomic, since the specific economic efficiency of their development is negative. However, the development of oil and gas resources of these territories may give a powerful impetus to the development of related sectors (science and industry), thereby increasing the potential of public economic efficiency and the priority of their development.

Therefore, the formation of an assessment criterion taking into account the strategic goals of the state (maximizing GDP and environmental security) can significantly change the outlook on the economic efficiency of Arctic hydrocarbon resources development and its predictive estimate. This means there is a high relevance for the use of such approaches in creating programs for economic development in the Arctic zone of Russian territories. Along with that, the use of domestic technologies and equipment has a great impact on the efficiency. In light of this, the priority of development of the resources should be determined in accordance with the level of readiness of related industries.

References

Gazeev M.H., Rybak A.B, Volynskaya N.A. (2015). Methodical aspects of estimation of oil and gas resources of the continental shelf and Far East. *News from higher educational institutions. Sociology. Economics. Politics.* Tyumen, TSOGU, 1 (44): 45 – 48.

Nazarov V.I., Kalist L.V. (2006). Ekonomicheskaya otsenka neftegazovogo potentsiala arkticheskogo shel'fa Rossii [Economic Assessment of Oil and Gas Potential of the Arctic Shelf of Russia]. *Neft'GazPromyshlennost' [OilGasIndustry],* St. Petersburg, 6(26): 22 – 24.

Regional and local US authorities require 34 billion USD from BP. (2013-1). *Oil and Capital.* oilcapital.ru/company/195904.html.

Required BP expenses caused by the Gulf of Mexico disaster. (2013-2). *Oil and Capital.* oilcapital.ru/company/195940.html.

Shirov A.A, Yantovskii A.A. (2011). Otsenka mul'tiplikativnykh effektov v ekonomike. Vozmozhnosti i ogranicheniya [The estimation of multiplicative effects in the economy. Capabilities and limitations]. *ECO Journal*, Novosibirsk, The editorial board of ECO, 2: 40 – 58. https://ecfor.ru/publication/otsenka-multiplikativnyh-effektov-v-ekonomike.

Shpurov I.V. (2017). Syr'yevaya baza uglevodorodnogo syr'ya rossiyskoy Arktiki i kontinental'nogo shel'fa. Perspektivy osvoyeniya. [Raw materials base of hydrocarbon raw materials of the Russian Arctic and continental shelf. Prospects for development.] rao-offshore.ru/netcat/RAO-2017/1/Shpurov_GKZ.pdf.