Methodological approaches to modelling extractive industry processes Sakha Republic (Yakutia)

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Abstract. In recent years the demand for fuel, energy and mineral resources of the Republic of Sakha (Yakutia) has been growing. Due to the redirection of raw material exports from the west to the east with the construction of the ESPO and Power of Siberia pipelines, special attention is being paid to the oil and gas resources of Western Yakutia and the coal resources of Southern Yakutia. Large mining companies operate in the region: Gazprom, Kolmar, Surgutneftegaz, Polyus, and others. How long they will continue the production activities in the region and how these activities will affect the socio-economic development of the region is the subject of research by many scientists. In this regard, modelling of extractive industry processes for long-term forecasting and planning is a highly relevant task. In the article, based on the analysis of existing approaches to modelling of extractive industry processes, the methodological approach most suitable for the deposits of the Republic of Sakha (Yakutia) is selected - the method of correlation and regression analysis with methodological tools for solving forecasting and planning problems. Since most of the phenomena and processes in the economy are constantly interrelated, the study of their dependencies and interrelations between objectively existing phenomena and processes plays an important role in the economy. It provides an opportunity to better understand the complex mechanism of cause-and-effect relationships between phenomena.

1 Introduction

The territory of the Republic of Sakha (Yakutia) contains many deposits of highly liquid, expert-oriented mineral resources such as diamond, oil, gas, coal, gold and others. The ESPO and Power of Siberia trunk oil and gas pipelines with access to the Asia-Pacific market are laid across its territory, involving major oil and gas condensate fields located in the southwest of the Republic - Talakan and Chayandinskoye. Also, a large amount of high-quality coking coal is exported by rail from the Elga coal deposit to Asia-Pacific countries. In this regard, in recent years there has been a sharp increase in the production of hydrocarbons (Fig.1).
It should also be noted that in recent years, with the development of new large gold deposits Gross and Tabornoye, the region has sharply increased the volume of gold production and is consistently ranked third in the country. In 2022, the region will produce a record 46 tons of gold. As for the diamond mining industry - the main budget-forming industry of the republic, on the contrary, there is a tendency of production decrease (Fig. 2), which is associated with the reduction of industrial reserves.

The economy of the northern regions of resource type specializing in subsoil use, as a rule, was formed historically, including for a long time as an integral component of the national economy in the conditions of directive, planned economy. Huge costs associated with the development and development of northern regions were compensated through the use of cross-subsidization mechanisms on a national scale [1]. It should be noted that in the territory of the northern regions in the absence of nationwide mechanisms of cross-subsidization naturally reduces the economic efficiency of subsoil use. In this regard, the research of methods of forecasting processes of extractive industry is very relevant.

The aim of the research is to choose a methodology for modeling forecasting processes as applied to the extractive industry of the Republic of Sakha (Yakutia).
2 Materials and Methods

The paper reviews and analyzes the existing methodological approaches to modeling of extractive industry processes, based on which the most suitable modeling method for the deposits of the Republic of Sakha (Yakutia) - correlation and regression analysis method that takes into account economic, social and environmental factors - is selected. The parameters of factors can be considered as indicators of official regional statistics, conjuncture of world and domestic markets of fuel and energy and mineral resources, individual indicators of subsoil users. The level of provision of large subsoil users in the region with mineral reserves was calculated. The input parameters for correlation and regression analysis of the forecast model are recommended.

3 Results

There are many methodological approaches to modeling of mining processes. In this case, many researchers take the volume of mineral extraction as the resulting indicator, but the factors affecting the result are taken different indicators-indicators. For instance, G.I. Arkhipov. [2] considers mineral resource potential and financing of geological exploration as the main factor. He believes that the low degree of geological exploration affects the low differentiation of subsoil use and the discovery of new deposits with effective reserves. Other researchers link the development of fields with transportation and energy accessibility. This factor is characteristic especially in the northern territories, where there are many fields concentrated in the unallocated subsoil fund. The production process in the northern territories is carried out mainly on a rotational basis.

Arkhipova Y.A. and Bardal A.B. [3] note that "nowadays there are tendencies to solve transportation problems at the expense of private investment. This not only leads to savings of financial resources by the state, but also increases the involvement, interest of large companies in the creation of full-fledged transportation chains of production and sales". The problems of energy supply are also solved at the expense of mining companies, which leads to an increase in the cost of production.

There is no denying the impact of the extractive industry on the socio-economic and environmental development of the territory of presence. Ivatanova N.P. believes that the economic and mathematical model should be represented by "the target function of growth of total regional income to calculate the maximum effect from the innovative use of mineral raw material potential of the region, taking into account a set of mining-ecological, social and economic constraints and inflationary processes" [4].

Frolov V.G., Kaminchenko D.I. [5] take into account the harmonization of interests of economic and non-economic subjects (stakeholders) of industrial policy of different forms of ownership and industry affiliation in the digital economy when building the model. One of them emphasizes the actor-activity approach, while the other - the content approach. These models reflect the interrelationships of different actors of industrial policy and their specific interests, and pay special attention to the systemic and synergetic effects formed due to their coordination and consideration. Interrelation and harmonization of stakeholders' interests contribute to the achievement of systemic effects, expressed, for instance, both at the level of industrial production efficiency indicators, and at the level of ensuring the quality of safety (ecology), etc.

Kaplan A.V. [6] developed a set of models for forecasting the conditions of socio-economic development of a mining enterprise. A methodological approach to the development of a strategy for sustainable development of a mining enterprise based on the forecasting of socio-economic conditions is proposed. Forecasting the conditions of socio-economic development is proposed to be carried out using methods of economic and
mathematical modeling, taking into account the combination of phases of cycles of endogenous and exogenous factors. The given set of models allows taking into account the socio-economic orientation of development goals and the cyclical nature of changes in endogenous and exogenous parameters of the environment.

A number of researchers adhere to modern approaches to modeling of mining processes, such as cluster-network and neural network approaches. For instance, Kozhemyakin L.V. [7] using these approaches predicted the profit of an oil and gas enterprise in the short term under different variations of the cluster load index.

Zhukov R.A. et al. [8] propose a socio-ecological-economic approach using a regression model to assess the state and prospects of development of the extractive industry of the region in interrelation with other subsystems, which allows to achieve the best economic, environmental and social results of functioning. The regression equation in accordance with the steppe multiplicative model (by analogy with the production function) for the volume of mineral extraction depending on the value of fixed assets and the number of people employed in the industry is constructed. To assess the extractive industry of the socio-ecological-economic system of the regions, a generalized performance indicator is used, formed on the basis of actual private indicators in relation to the normative ones, taking into account the dependencies between them. In order to compare the regions as a whole and by individual constituent subsystems and factors, it is proposed to use an integral indicator of assessment of the subsystem "Mining" of the socio-ecological-economic system of the region.

Margaryan E. [9] proposes a regression-based counterfactual simulation approach using location-level industry data to systematically analyze how the relationships between different industries and the growth regimes that these relationships constitute differ across regions and how these differences affect the response of regional development to interventions. This approach is based on full descriptive panel regression models that decompose agglomeration effects into sectoral, secondary and structural effects.

4 Discussion

For modeling the processes of mineral extraction we have chosen the method of correlation and regression analysis, which is a methodological toolkit for solving forecasting and planning problems. Since most phenomena and processes in the economy are in constant interrelation, therefore research of their dependencies and interrelations between objectively existing phenomena and processes plays a great role in the economy. It provides an opportunity to better understand the complex mechanism of cause-and-effect relations between phenomena.

Correlation and regression analysis is a set of regression and correlation methods that characterize the relationships between economic variables. Construction and analysis of the correlation model are carried out in stages: preliminary analysis, collection of information, primary processing, model construction, evaluation and analysis of the model.

The form of correlation relationship can be expressed by various mathematical functions [10].

Depending on the number of factors, simple (pairwise) and multiple regression are distinguished. Pairwise regression is a regression between two variables, i.e., a model or equation of the following form:

$$\hat{y}_x = f(x)$$

where:

- \(\hat{y}_x\) – effective feature
- \(x\) – factorial feature

Multiple regression is a regression of an effective feature with two or more factors, i.e., a model of the following form:

$$\hat{y}_{x_1, x_2, \ldots, x_n} = f(x_1, x_2, \ldots, x_n)$$

where:

- \(\hat{y}_{x_1, x_2, \ldots, x_n}\) – effective feature
- \(x_1, x_2, \ldots, x_n\) – factorial features.
\[ x_1, x_2, \ldots, x_n \text{ - factor features} \]

The regression equation is always supplemented with indicators of closeness of relationship. For instance, in linear regression such an indicator is the linear correlation coefficient, which modulo should not exceed unity:

\[ r_{xy} = \frac{\bar{xy} - \bar{x} \bar{y}}{\sigma_x \sigma_y} \]

where:

- \( r_{xy} \) - linearity correlation coefficient;
- \( y \) - effective feature;
- \( x \) - factorial feature.

Determination coefficient shows how much of the fluctuation of the effective feature is explained by the change in the factorial feature and is determined by the following formula:

\[ D_{xy} = r_{xy}^2 \times 100\% \]

here:

- \( D_{xy} \) - determination coefficient;
- \( r_{xy} \) - correlation coefficient.

Also, during the analysis the elasticity coefficient is calculated, which shows by how many percent on average the effective feature changes if the factorial feature changed by 1%.

The main role in modeling the forecasting of the extractive industry processes is played by the level of provision of subsoil users with mineral reserves. On the territory of the Republic of Sakha (Yakutia) the major Russian companies PJSC “Surgutneftegaz”, PJSC “Gazprom”, OJSC “Polyus”, OJSC “Norgold”, PJSC “Kolmar”, PJSC “ALROSA”, etc. are engaged in the extraction of minerals. The main factor for their long-term efficient operations is the supply of reserves. Availability of diamond and gold reserves is low, but with proper investment in geological prospecting and exploration works this indicator may increase (Table 1).

**Table 1. Availability of balance reserves of minerals of the main extractive enterprises**

<table>
<thead>
<tr>
<th>Deposits</th>
<th>Mineral</th>
<th>Unit of measurement</th>
<th>Stocks A+B+C1</th>
<th>Production in 2021</th>
<th>Provided stocking of supplies, years</th>
</tr>
</thead>
<tbody>
<tr>
<td>PJSC Surgutneftegaz</td>
<td>Oil</td>
<td>mln. t</td>
<td>145.51</td>
<td>10.30</td>
<td>14</td>
</tr>
<tr>
<td>Taas Yuryakh Neftegazodobycha LLC</td>
<td>Oil</td>
<td>mln. t</td>
<td>93.72</td>
<td>5.03</td>
<td>18</td>
</tr>
<tr>
<td>PJSC “Gazprom”</td>
<td>Combustible gas</td>
<td>bln m3</td>
<td>1385.83</td>
<td>11.49</td>
<td>&lt;100</td>
</tr>
<tr>
<td>OJSC Yakutsk Fuel and Energy Company</td>
<td>Condensate</td>
<td>mln. tons</td>
<td>272.09</td>
<td>1.91</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Coal</td>
<td>Ethane</td>
<td>thous. t</td>
<td>16348</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>Propane</td>
<td>thous. t</td>
<td>8464</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>Butane</td>
<td>thous. t</td>
<td>3969</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>JSC Elgaugol</td>
<td>Coal</td>
<td>mln. t</td>
<td>1566.38</td>
<td>13.97</td>
<td>&lt;100</td>
</tr>
<tr>
<td>JSC Inaglinsky Mining and Processing Division</td>
<td>Coal</td>
<td>mln. t</td>
<td>518.10</td>
<td>2.79</td>
<td>&lt;100</td>
</tr>
</tbody>
</table>

5
To build a forecast model of field development as factorial features we can offer classes of factors distributed in blocks: economic, social and environmental, which, in turn, consist of the indicators of official statistics and production and economic indicators of subsoil users. Here it should be noted that we have selected only publicly available indicators, if necessary, we can vary other indicators, for instance, technical ones, such as average metal content in ore, volume of stripping works, production capacity of the enterprise, etc. (Table 2).

**Table 2. Input parameters of the forecast model of mineral production volumes**
### Production capacity
- Gross regional product.
- Volume of shipped goods of own production by FEA "Mining Operations".
- Investments in fixed assets by FEA "Mining Operations".
- Cost of fixed assets in the FEA "Mining Operations".
- Costs of fuel and energy resources.

### Export potential
- Ruble exchange rate relative to the US dollar.
- Export volume of goods by region.
- Export volumes of the Russian Federation by types of minerals (oil, natural gas, coal, diamond, gold).
- Export prices for Urals and Brent oil, coking and steam coal, natural gas, LNG, gold, diamonds.

### Social Block
- Employment rate
- Population (end of year estimate)
- Average annual number of employed persons, total including those employed in mining and quarrying
- Level of money income of the population
- Average monthly nominal wages.
- Average per capita cash income of the population.
- Consumer expenditures of the population per 1 inhabitant per month.
- Living standard of the population
- Total area of residential premises per person.
- Availability of doctors per 10 thousand population.
- Cost of a fixed set of goods and services per month.
- Length of public roads.

### Environmental Block
- Impact on atmospheric air
- Emissions of pollutants into the atmospheric air from stationary sources.
- Impact on water resources
- Discharge of polluted wastewater into surface water bodies.
- Impact on land resources
- Total volume of generated production and consumption waste.

Using the interdependence of these parameters it is possible to describe the equation of the mathematical model of the resulting attribute, which can be the volume of mineral production.

The mathematical model can be described by the following multiple regression equation:

\[ Y = a_0 + a_1 x_1 + \ldots + a_i x_i \]

Here:
- \( Y \) – effective feature
- \( a_0 \) – is an absolute term of the equation
- \( a_i \) – regression coefficients.

### 5 Conclusions

Conclusions therefore, we have chosen the method of correlation and regression analysis from a variety of methodological approaches to modelling the process of extractive industry. The advantage of this approach is that in order to assess the extractive industry of the socio-ecological-economic system of regions we use a generalized performance indicator formed on the basis of actual private indicators in relation to normative ones, taking into account the dependencies between them, which allows us to achieve the best economic, environmental and social results of functioning. On the basis of the generalized performance indicator, it is possible to assess the state and prospects of development of individual branches of the extractive industry with different conditions, to identify significant factors influencing the \( \ldots \)
processes of the extractive industry. Indicators of efficiency and effectiveness of extractive industry processes allow to justify the need for management decisions to achieve sustainable development trajectories of the region, taking into account the changes occurring in the industry. This approach also makes it possible to identify development reserves, the realization of which will allow not only to increase production volumes, but also to increase the industry's contribution to the sustainable socio-economic development of the area of presence.

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References

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