Analysis of sustainable development of the Arctic territories of the Russian Federation

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Abstract. The problem and the global objective of organizing and managing development is to develop a set of interrelated measures for sustainable development of the Arctic territories of the Russian Federation. This article considers the factographic approach using Autoregressive Distributed Lag (ADL) model for the analysis of sustainable development of the Arctic territories. A set of interrelated measures relates to the main spheres of human activity in the Russian Arctic, namely, to activities in four areas: environmental, industrial, innovative, socio-economic. The main factors influencing the sustainable development of the Arctic regions of the Russian Federation are identified based on structural analysis of the problems associated with the sustainable development of the territory. Indicators that represent the spheres of human activity in the Arctic, whose interaction is contradictory when moving towards sustainable development, are taken as endogenous factors. Based on the indicators substantiated in this paper, the mathematical model of factor dependence was developed and a set of measures was presented that are necessary to reduce the degree of risk in order to solve the given problem.

1. Introduction
Recently, there has been a sustained interest of the world community in the Arctic region. The Arctic refers to the global strategic regions having huge natural potential including mineral resources, fuel, energy and forest resources. The world scientific literature shows an interest in analysis of sustainable development of the Arctic territory. Therefore, it is important to study this topic more thoroughly and make the economic analysis of sustainable development processes.

Among the methods for analyzing sustainable development of the territory the factographic analysis method with plotting the mathematical model of factors correlation is promising. The essence of this method is to extract facts that characterize objects and relations between objects from the analysis of proceeding processes based on the study of models that reflect interdependent influence of objects and relations between objects [1], [3], [2].

The purpose of this article is to build and study Autoregressive Distributed Lag (ADL) model for the analysis of sustainable development of the Arctic territories of the Russian Federation.

2. Literature review
When analyzing works on this issue, we can find works related to both general modeling problems and research, which use more specific instruments for considering sustainable development.

The review of territorial development modelling showed that the problems of modelling the development of the Arctic territories, as well as related issues were studied by N. Didenko, D. Skripnyuk, O. Mirolyubova, A. Popkova, S.V. Kulik, E.S. Romashkina, V. Sevashkin, E.
Samylovskaya, K.N. Kikkas [3], [4], [5], [6], [7], [8]. In their studies, scientists based on the features of sustainable development of the Arctic regions [9], [10], [11].

There are papers wherein it is emphasized that the richness and diversity of the natural resource base, attractive tourist and recreational potential contribute to the implementation of provisions of the sustainable development of the Arctic territory and, therefore, require reflection of these factors in the integrated approach for the analysis of sustainable socio-economic growth [12], [13], [14], [15], [16].

Besides that, the study of the Arctic climate, the impact of human activities on climate, the impact on environment in all spheres of human life should also be reflected in the analysis of sustainable development in all areas of human life [17], [18], [19].

3. Representation of sustainable development of the Arctic territories of the Russian Federation

The general concept of considering the problem of sustainable development of the Arctic regions of the Russian Federation includes several main objects, whose interaction creates conflicting directions for sustainable development.

1) Ecological sphere. The United Nations Environment Programme identifies the following major environmental issues in the Arctic region: melting Arctic ice and climate change; water pollution of the northern seas by drains of oil and chemical compounds as well as by sea transport.

The main measures for implementation of environmental safety in the Arctic zone of the Russian Federation are: stipulation of special treatment of nature management and environmental protection; reclamation of natural landscapes; disposal of toxic industrial waste.

This sphere can be evaluated using the indicator - Air pollutant emissions from stationary sources ($Y^4_t$).

2) Production sphere. Resource and feedstock industries of northern territories may become locomotive of economic development. However, the primary state policy objective is to shift away from resource-export model of economic development to innovative-resource one with simultaneous focus on expanding the capacity of the domestic market.

The main problem of increasing the efficiency of industrial complex of the Arctic zone is its high dependence on the import of high-tech products and technologies along with the weak business demand for innovative development and insufficiently active position of authorities in supporting the cooperation of entities involved in the innovation process.

In assessing this sphere, there can be used such indicators as the gross regional product (GRP) share of the Arctic regions in the total GRP of the Russian regions ($Y^1_t$), the export share of the Arctic regions in the total export of the Russian regions ($Y^2_t$) and the shipping volume of the Arctic regions of the Russian Federation ($Y^5_t$).

3) Innovation sphere. Regarding the innovative development of the Arctic zone of the Russian Federation, it can be said that the priority is the development and implementation of technologies for extracting hard-to-recover hydrocarbon reserves in extreme conditions. Such developments may lead to increase in hydrocarbon extraction at the production level in the Persian Gulf. It is also important to consider the extremely low exploration maturity of the number of the most important mineral and energy resources.

The problems and prospects for the development of the Arctic region are mainly related to the development of world technologies. In the context of globalization of scientific, technological and industrial fields, the international role of the Arctic is determined by its scientific, technological and industrial potential.

The indicator that helps to assess the innovation sphere is R&D expenses ($Y^6_t$).

4) Social sphere. The living standards in the Arctic are quite low. The development of Arctic regions of the Russian Federation in the social sphere requires the support of small businesses. The interaction of large corporations and small businesses will have beneficial effect on the region social situation.

The social sphere can be evaluated using the indicator - Average salary in the Arctic zone of the Russian Federation ($Y^3_t$).
The following variables will be exogenous indicators: $X^1_t$ - Payment of funds for import of technologies and technical services, $X^2_t$ - Workforce productivity, $X^3_t$ - Number of visits to a doctor, $X^4_t$ - Workforce productivity growth rate, $X^5_t$ - Fixed investment, $X^6_t$ - Population growth, $X^7_t$ - Energy consumption, $X^8_t$ - Marriage rate per 1000 people, $X^9_t$ - Number of scientists, $X^{10}_t$ - Number of hospital beds per 10,000 people, $X^{11}_t$ - Manufacturing index, $X^{12}_t$ - Number of state and municipal educational institutions [2].

4. Methodology of mathematical modelling

The system of equations in their general form is presented below:

$$
Y^1_t = f(Y^1_{t-1}; Y^2_t; x^1_t; x^2_t; x^3_t)(1)
$$

$$
Y^2_t = f(Y^2_{t-1}; Y^5_t; x^4_t; x^5_t; x^6_t; x^{10}_t; x^{12}_t; x^8_t)(2)
$$

$$
Y^3_t = f(Y^3_{t-1}; Y^1_t; Y^3_t; x^4_t; x^6_t; x^{10}_t; x^{12}_t; x^8_t)(3)
$$

$$
Y^4_t = f(Y^4_{t-1}; Y^3_t; x^4_t; x^5_t; x^6_t)(4)
$$

$$
Y^5_t = f(Y^5_{t-1}; Y^2_t; x^1_t; x^2_t; x^6_t; x^{11}_t)(5)
$$

$$
Y^6_t = f(Y^6_{t-1}; x^1_t; x^2_t; x^6_t; x^9_t)(6)
$$

The model’s structural form in its general form before the completion of exogenous variable selection stages consisting of six interconnected models shows interdependence of endogenous and exogenous variables. Each structural form equation is written as ADL model. [4]

$$
\begin{align*}
Y^1_t &= a_0 + a_1 Y^1_{t-1} + a_2 Y^3_{t-1} + a_3 X^1_t + a_4 X^2_t + a_5 X^3_t \\
Y^2_t &= a_0 + a_1 Y^2_{t-1} + a_2 Y^5_{t-1} + a_3 X^4_t + a_4 X^5_t + a_5 X^6_t \\
Y^3_t &= a_0 + a_1 Y^3_{t-1} + a_2 Y^1_{t-1} + a_3 Y^5_{t-1} + a_4 X^4_t + a_5 X^6_t + a_6 X^{10}_t + a_7 X^{12}_t + a_8 X^9_t \\
Y^4_t &= a_0 + a_1 Y^4_{t-1} + a_2 Y^5_{t-1} + a_3 X^4_t + a_4 X^5_t + a_5 X^6_t \\
Y^5_t &= a_0 + a_1 Y^5_{t-1} + a_2 Y^2_{t-1} + a_3 X^2_t + a_4 X^5_t + a_5 X^{11}_t \\
Y^6_t &= a_0 + a_1 Y^6_{t-1} + a_2 X^1_t + a_3 X^2_t + a_4 X^6_t + a_5 X^9_t
\end{align*}
$$

In systems of simultaneous equations endogenous variables depend on both exogenous and endogenous variables. The system’s structural form is its presentation wherein more than one endogenous variable can be present in the equations (in standard notations this means that there are endogenous variables, i.e. regressors, on the right side of equations).

The system’s structural form should be transformed into its reduced form wherein each equation has only one endogenous variable, i.e. endogenous variables are expressed in terms of exogenous ones.

The equation, which is designed to evaluate the industry, is written using the Cobb-Douglas function. The Cobb–Douglas function is the resource-production ratio that reflects dependence of the production volume Q on production factors that create it - labour costs L and capital K [5].

The function’s general form:

$$
Q = A \times L^\alpha \times K^\beta
$$

where $A$ is the technological coefficient, $\alpha \geq 0$ is labour elasticity coefficient, and $\beta \geq 0$ is capital elasticity coefficient.

ADL model has the following form:

$$
Y_t = \sum_{i=1}^{k^1} a_0 y_{t-i} + \sum_{i=1}^{k^2} a_1 x^1_{t-i} + \sum_{i=1}^{k^3} a_2 x^2_{t-i} + \sum_{i=1}^{k^4} a_3 x^3_{t-i} (9)
$$

Where $k^1, k^2, k^3, k^4$ - is number of lags of variables

The Dickey-Fuller test is used to check series for stationarity.

Provided the series is non-stationary, it is reduced to the stationary form by calculating the differences. The Dickey-Fuller test is autoregressive equation in the form of:

$$
y_t = a y_{t-1} + \epsilon_t (10)
$$

where $y_t$ is the time series, $a$ $\epsilon_t$ is the error.
If $|a| < 1$, then the series is stationary. If $a=1$, then the process has a unit root, in this case the series is not stationary, it is the integrated time series of the first order. The Dickey-Fuller test is performed by solving the first-order autoregressive equation in Excel.

The selection of exogenous variables was carried out using the multicollinearity procedure. If the pairwise correlation coefficient exceeded $|0.7|$, then one variable from the pair was excluded from the further analysis, if it was justified from the economic point of view.

The verification of pair correlation coefficients for significance was determined using Student’s $t$-criterion. If $t_{calc} \geq t_{table}$, then the obtained coefficients are significant, i.e. the sample corresponds to the general population. To assess the significance of correlation coefficients, the Student’s $t$-test was calculated for each pairwise correlation using the formula:

$$T_{calc} = \sqrt{\frac{r_{xi,xj}^2}{1-r_{xi,xj}^2} (n-2)} \quad (11)$$

With significance level of $\alpha=0.05$, the number of degrees of freedom is $n-2=7$ for the first level and $n-2=5$ for the second level, for the first level $T_{table} = 2.36$ and $T_{table} = 2.5$, for the second level.

Autocorrelation of indicators was checked to select those lags that have strong correlation with the indicator value in the last period. Autocorrelation of indicators was checked in Excel. The check was carried out using the CORREL function which enables to find the correlation between the original series and the lag.

In order to transform the structural form of the equation system into the reduced one, its identifiability was analyzed by the following criterion:

$$D+1 > H \quad \text{-- the equation is superidentifiable.}$$

where $H$ is the number of endogenous variables in the $i$-th equation of the system; $D$ is number of exogenous variables that are contained in the system but not included in this equation.

The model coefficients were found using the least square method.

The model reliability was checked using the Fisher’s $F$-test and the determination coefficient, and the reliability of equations coefficients - using the Student’s $t$-test.

If $F_p \geq F_{ph}$, then the constructed model is significant, i.e. the sample corresponds to the general population. The closer the determination coefficient to 1, the more accurate the model is, that is, the coefficient should be no less than 0.7 ($R^2 \geq 0.7$). [11]

The Fisher’s $F$-test is calculated by the formula:

$$F = \frac{R^2}{1-R^2} \times \frac{f_2}{f_1} \quad (12)$$

where $R$ is the correlation coefficient; $f_1$ and $f_2$ – the number of degrees of freedom. [12]

The first fraction in the equation is equal to the ratio of the explained variance to the unexplained one. Each of these deviations is divided by the degree of freedom (the second fraction in the expression). The number of degrees of freedom of the explained variance $f_1$ is equal to the number of explicative variables of the linear model. The number of degrees of freedom of the unexplained variance is $f_2 = T-k-1$, where $T$ is number of time periods, $k$ is number of explicative variables. To check the significance of the regression equation, the calculated value of the Fisher’s criterion is compared with the table value taken for the number of degrees of freedom $f_1$ (large variance) and $f_2$ (lower variance) at a selected significance level (usually 0.05). If the calculated Fisher’s criterion is higher than the table one, then the explained variance is much larger than the unexplained, and the model is significant [13].

The ultimate system of equations with the calculated coefficients is as follows:
5. Discussion

Analyzing the obtained model, it can be noted that in order to solve the given problem, namely, to continue the sustainable development of the Russian Federation territories, it is necessary to reduce the degree of risk [20], [21], [22]. A whole set of measures should be taken, such as: to increase the state budget allocated for development of the Arctic territories as well as for the related regions; develop regulatory documents governing nature management taking into consideration the peculiarities of the Arctic climate and relief; establish new social facilities as well as increase spending on health and education; renew production capacities; develop small business; update the transport infrastructure and improve the logistic systems in regions; improve the investment climate in the region, attract new companies, including the foreign ones; develop current and new deposits considering the environmental conditions of the Arctic region.

It is important to remember that the solution for the problem of sustainable development and the set of measures associated with it will have the beneficial effect not only on the Arctic territories of the Russian Federation, but also on the entire Arctic zone and countries associated with it.

The decisive goal of the Russian Federation’s state policy in the field of sustainable development of the Arctic should be to ensure the balanced solution of environmental and socio-economic development problems in the interests of present and future generations based on the efficient use of natural resources, maintaining the traditional way of life of indigenous peoples of the North, improving the quality of life and public health; restoration of disrupted natural systems, as well as strengthening the national security of Russia in the Arctic.

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