Sustainable development and environmental security in the countries of the circumpolar north

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Abstract. The article presents a comparative analysis of the sustainable development of eight circumpolar countries: Norway, Sweden, Finland, Russia, the USA, Canada, Denmark, and Iceland. Sustainability is understood as the interdependent development of five spheres of human activity: economic, industrial, social, demographic, innovative-technological, and ecological. Each sphere is assessed in terms of endogenous variables that are influenced by exogenous factors. The demographic sphere is evaluated by population; the social – by the human development index (HDI); economic-industrial – GDP per capita (PPP); environmental – extent of exposure of the population to particulate matter in the atmosphere having a diameter of 2.5 μm; innovative-technological – by high-tech exports. The novelty lies in the analysis of the sustainable development of the respective countries using ADL-modelling. Five interdependent econometric equations are presented along with a method for calculating coefficients. The concept of economic, social and environmental sustainability coefficients is introduced. Each country's sustainability index was calculated as the geometric mean index of economic, social and environmental sustainability. The results of a comparison of the circumpolar countries according to the sustainable development index are presented. The model can predict the development of each sphere of the respective country's life-sustaining functions and determine the predicted values of the country's sustainable development index, as well as to compare the development of countries on sustainable development and environmental safety.

1 Introduction

Ensuring sustainable development is one of the most pressing issues facing all countries of the world. The goal is to ensure economic growth at the same time as protecting the resource base and the environment, taking the interests of future generations into account. This topic is becoming increasingly urgent due to the growth in human impacts on the environment, which entail negative consequences for the biosphere. Due to current social demands, the gap between human needs and the capabilities of the biosphere to support them is increasing. Currently, not only does the consumption of mineral resources double

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globally every 10 years, but more than 90% of the resources used by humans go to waste, resulting in serious damage to the environment.

Under such conditions, the future both of humanity and the natural environment are under threat [1]. In order to maintain a viable state of the environment and avoid global shocks, national governments must develop effective state-led development strategies [2]. The United Nations Conference on Environment and Development (Rio de Janeiro, 1992) and the United Nations Conference on Sustainable Development (RIO+20, Rio de Janeiro, 2012) were devoted to analysing the sustainable development of social and economic systems bringing together the work of many diverse research teams.

The term "sustainable development" was coined at the World Conference on the Environment in Stockholm in 1972. However, in 1992, at the UN Conference on Environment and Development in Rio de Janeiro, the same term was used to refer to a new concept applying to the existence of humanity as a whole and in the context of attempting to overcome the problems associated with overpopulation, irreplaceable use of natural resources and pollution of the environment.

All UN member states have compiled a list of 17 sustainable development goals that they intend to achieve by 2030, among them:

- pervasive eradication of poverty in all its forms;
- elimination of hunger, ensuring food security and improving nutrition, as well as promoting sustainable agriculture;
- ensuring a healthy lifestyle and promoting well-being for all at all ages;
- providing inclusive and equitable quality education and promoting lifelong learning for all;
- ensuring gender equality and the empowerment of all women and girls;
- ensuring the availability and rational use of water resources and sanitation for all;
- ensuring universal access to affordable, reliable, sustainable and modern energy sources for all;
- promoting inclusive and sustainable economic growth, full and productive employment and decent work for all;
- building resilient infrastructure, promoting inclusive and sustainable industrialisation and innovation;
- reducing inequalities within and between countries;
- ensuring the openness, security, resilience and environmental sustainability of cities and towns;
- ensuring the transition to rational models of consumption and production;
- taking urgent measures to combat climate change and its consequences;
- conservation and rational use of the oceans, seas and marine resources for sustainable development;
- protection and restoration of terrestrial ecosystems and their rational use; rational forest management, combating desertification, halting and reversing land degradation and halting the loss of biodiversity;
- promoting a peaceful and inclusive society for sustainable development, ensuring access to justice for all and creating effective, accountable and participatory institutions at all levels;
- strengthening the means of implementation and revitalising the work of the Global Partnership for Sustainable Development [3].

In this article, we set out to compare the development of eight circumpolar countries on the basis of the conceptual principles of sustainable development [4-7]. To this end, a model for the sustainable development of the circumpolar countries has been developed using the ADL-modelling method. The model reflects three areas of sustainable development: social, economic and environmental.

2 Social aspect of the concept of sustainable development

The concept of sustainable development recognises that, in order to reduce poverty and achieve overall prosperity for the population, as well as to meet the needs of future generations, growth must be of benefit to all at the same time as being environmentally sound. Social, economic and environmental development should and carefully planned taking the availability of resources into account.

Thus, the concept of sustainable development has a social orientation [8]. It aims to preserve social and cultural stability, including reducing the number of destructive conflicts. On a global scale, it is also desirable to preserve cultural capital and more fully utilise sustainable development practices. In order to achieve sustainable development, contemporary societies will have to create more efficient decision-making systems that take different historical experiences into account. Therefore, in the absence of equitable distribution of resources and opportunities among all members of human society, sustainable development as such is impossible. Achieving a decent standard of living and well-being for all citizens of the world should be the primary goal of the world community. For sustainable development, it is first necessary to create a more equal society at all levels of human organisation without exception. Some guaranteed minimum standard of living or stable quality of life should be the inalienable right of any citizen. Stable quality of life from the social perspective is understood in terms of the existence of such benefits as:

- covering minimum basic needs;
- surpassing these needs to the extent that it improves quality of life (although it is also recognised that an excessive amount will not be sustainable and, ultimately, will result in deterioration);
- including such elements as a healthy lifestyle, employment opportunities, access to education and medical services, a congenial environment, personal safety, participation in public affairs and individual fulfilment.

In applying the methods for assessing the sustainable development of countries, the selection of statistical indicators plays an important role. In order to assess social development, most researchers identify the following indicators that can be used in the analysis: number of unemployed; unemployment rate; consumer spending per capita on average; proportion of the population with cash incomes below the subsistence minimum; proportion of household spending on housing and utilities; proportion of education to total budget expenditures; proportion of health to total budget expenditures; budget expenditures for the implementation of measures of social support for particular categories of citizens; number of reported crimes per 100,000 people; morbidity per 1000 people.

In the present work, the human development index (HDI) was adopted to serve as a general indicator for assessing social development [9].

3 Economic aspect of sustainable development

From an economic point of view, the concept of sustainable development is based on John Hicks' definition of income. Economic development can be described as sustainable when the state of the economy is such that the stability of output (final) parameters of the development of production, social and economic indicators is maintained.

The significance of the economically optimal use of limited natural resources can be directly derived from Hicks' definition of income. Here, it is important to recognise that the core concept of sustainable development is informed by an economic perspective.

The following statistical indicators can be used to assess economic development: GDP per capita; per capita income; average monthly wages; fixed investment; subsistence minimum; internal research and development costs; cost of fixed assets; depreciation of

basic production assets. In the study, GDP per capita (PPP) was a used as a generalised indicator for assessing economic development [10].

4 Environmental aspect of sustainable development

From an environmental point of view, sustainable development should ensure the stability of biological and physical systems. Here, the viability of local ecosystems, on which the global stability of the biosphere as a whole depends, is of particular importance. Moreover, the concept of natural systems and habitats can be understood broadly as also comprising human-created environments such as cities. rimary attention is paid to maintaining the abilities of such systems to cope with change rather than preserving them in some "ideal" static state. However, degradation of natural resources, environmental pollution and loss of biological diversity reduce the ability of ecological systems to heal themselves.

Environmental sustainability is the ability of an ecosystem to maintain its structure and functional features when exposed to external and internal factors. Quantifying the level of environmental sustainability of countries is typically estimated by the "Environmental Sustainability Index" (ESI) of the Yale Center for Environmental Law and Policy and the Colombian Center for the International Earth Science Information Network. The index is based on the evaluation of 76 parameters, including indicators of the state of ecosystems, environmental stress, environmental aspects of public health, social and institutional capacities and the international activity of the state [11 - 14].

The following statistical indicators can be used to assess environmental development: proportion of expenditures on environmental protection in the budget; emissions of pollutants into the atmosphere; discharge of polluted sewage into water bodies; area of afforestation; area of arable land.

A general indicator for assessing environmental development is based on the assumption that solid particles in the atmosphere having a diameter of 2.5 μm will have an impact on the population.

5 Methodology and Model

The sustainability analysis of the development of circumpolar countries is based on the construction of an ADL model for each country, comprising a system of five interdependent econometric equations and a subsequent forecast of the development of endogenous indicators.

In order to analyse the sustainable development of the circumpolar countries, the development of each country was considered in terms of the following five spheres of life-sustaining activity: economic production, social, demographic, innovative-technological, and ecological [8].

The purpose of the living environment analysis was to identify indicators for evaluating domains and factors affecting the living environment. As a result of the analysis, the following points were identified.

The demographic sphere of life-sustaining activities, which is evaluated by population, is impacted by the number of doctors and government spending on health care, the sphere of economic production (as estimated by per capita GDP (PPP)) and the ecological sphere (expressed in terms of the exposure of the population to 2.5 μm diameter solid particles).

The social sphere of life-sustaining activity, evaluated by HDI, is impacted by: expenditures on education; the economic-production sphere estimated by GDP per capita (PPP) and the ecological sphere estimated by the quantity of solid particles with a diameter of 2.5 μm per unit of population.

The economic and production sphere of life, as evaluated by GDP per capita (PPP), is impacted by foreign direct investment, employment, export of goods and services, inflation, the demographic sphere of life-sustaining activity (estimated by population), the innovative-technological sphere (estimated by high-tech products) and the environmental sphere (estimated by the exposure to solid particles with a diameter of 2.5 microns on the part of the population).

The innovation and technological sphere of life-sustaining activity, as evaluated by the export of high-tech products, is impacted by the costs of research and development, the number of patent applications and the social sphere of life activity (assessed by HDI).

The ecological sphere of life-sustaining activity, evaluated in terms of the effect of solid particles of a diameter of 2.5 μm, is impacted by the volume of CO2 emissions, the Industrial Production Index (IPI) and economic-production (estimated by GDP per capita (PPP)).

Endogenous variables: Y1 – Population; Y2 – human development index; Y3 – GDP per capita (PPP); Y4 – export of high-tech products; Y5 – exposure of the population to solid particles with a diameter of 2.5 μm (μg per cubic metre).

The following exogenous indicators are identified: number of doctors, X1a; public spending on health care (% of GDP), X2a; public expenditures on education (% of GDP), X1b; foreign direct investment (million USD), X1c; employment (% of the population), X2c;

Exports of goods and services (million USD), X3c; inflation (%), X4c; R&D expenditures (% of GDP), X1d; number of patent applications, X2d; CO2 emissions (in kilotons), X1f; industrial production index (% of the base year (2010)), X2f.

The method of constructing a model of sustainable development of countries consists in building a model of autoregressive and distributed lag and subsequent analysis of its components at different stages.

The autoregressive distributed lag (ADL) comprises a time series model in which the current values of a series depend on both the past values of this series and the current and past values of other time series. The ADL model comprises a system of interdependent econometric equations.

The structural form of the model was compiled at the theoretical level; on the whole, this was applicable to each country. This takes the following form:

$$\begin{Bmatrix} Y_1 = a_0 + a_1 \cdot X_{1a} + a_2 \cdot X_{2a} + a_3 \cdot Y_3 + a_4 \cdot Y_5 \\ Y_2 = b_0 + b_1 \cdot X_{1b} + b_2 \cdot Y_3 + b_3 \cdot Y_5 \\ Y_3 = c_0 + c_1 \cdot X_{1c} + c_2 \cdot X_{2c} + c_3 \cdot X_{3c} + c_4 \cdot X_{4c} + c_5 \cdot Y_1 + c_6 \cdot Y_4 + c_7 \cdot Y_5 \\ Y_4 = d_0 + d_1 \cdot X_{1d} + d_2 \cdot X_{2d} + d_3 \cdot Y_2 \\ Y_5 = f_0 + f_1 \cdot X_{1f} + f_2 \cdot X_{2f} + f_3 \cdot Y_3 \end{Bmatrix} \quad (1)$$

The economic sustainability ratio was calculated as the ratio of the forecast value of GDP per capita (PPP) of the particular country to the highest forecast value of GDP per capita among all countries. The environmental sustainability coefficient was calculated as the ratio of the predicted value of the volume of the populations' exposure to solid particles with a diameter of 2.5 μm of one country to the highest predicted value of this exposure on the part of the population in other countries. The economic sustainability ratio was calculated as the ratio of the forecast value of GDP per capita (PPP) of the particular country to the highest forecast value of GDP per capita among all countries.

At the initial stage, statistics for the years 1996-2016 were collected on selected indicators describing the development of the five spheres of human activity. Data was obtained from the World Bank sites [https://data.worldbank.org/indicator], OECD [https://data.oecd.org/healthres], United Nations Development Program [https://www.un.org/sustainabledevelopment] and the Rosstat site [http://www.gks.ru].

A test for stationarity was carried out on all indicators that are associated with other variables. On the basis of the Dickey-Fuller test, it was concluded that all series of indicators are stationary and can be used in further analysis.

Consequently, following the determination of the relevant coefficients for each country, models were constructed.

The sustainable development model on the example of Russia is shown below.

$$\left\{\begin{array}{c} Y_1 = 19514739{,}12 + 0{,}774 \cdot Y1_{t-1} + 0{,}195 \cdot Y1_{t-2} - \\ -31922342{,}475 \cdot Y2 + 2888576{,}3 \cdot Y2_{t-1} + 6033936{,}35 \cdot Y2_{t-2} + \\ +94{,}639 \cdot Y3 + 8{,}89 \cdot Y3_{t-1} + 42{,}32 \cdot Y3_{t-2} \\ Y_2 = 0{,}769 + 0{,}075 \cdot Y2_{t-1} + 0{,}144 \cdot Y2_{t-2} - 0{,}004 \cdot X1b - \\ -0{,}00095 \cdot X1b_{t-1} - 2{,}65 \cdot Y1 + 2{,}39 \cdot Y1_{t-1} + 2{,}249 \cdot Y1_{t-2} + \\ +2{,}474 \cdot Y3 + 8{,}853 \cdot Y3_{t-1} + 2{,}148 \cdot Y3_{t-2} \\ Y_3 = -364928{,}452 - 0{,}19 \cdot Y3_{t-1} - 0{,}375 \cdot Y3_{t-2} - 0{,}056 \cdot Y1 + \\ +0{,}03 \cdot Y1_{t-1} + 0{,}042 \cdot Y1_{t-2} + 24013{,}64 \cdot Y2 + 331965{,}767 \cdot Y2_{t-1} + \\ +688{,}955 \cdot Y6 + 0{,}130 \cdot X3c + 0{,}045 \cdot X3c_{t-1} + 0{,}084 \cdot X3c_{t-2} \\ Y_4 = 18{,}173 + 8{,}249 \cdot X1d - 0{,}008 \cdot X2d - 0{,}003 \cdot X2d_{t-1} \\ Y_5 = 50{,}464 + 0{,}000013 \cdot Y1 + 0{,}000059 \cdot Y1_{t-1} - 0{,}000058 \cdot Y1_{t-2} - \\ -18{,}71 \cdot Y2 - 144{,}85 \cdot Y2_{t-1} + 0{,}00011 \cdot Y3 + 0{,}000027 \cdot Y3_{t-1} - \\ -0{,}00015 \cdot Y3_{t-2} - 0{,}00006 \cdot X1f - 0{,}036 \cdot X2f + 0{,}299 X2f_{t-1} + \\ +0{,}077 \cdot X2f_{t-2} \end{array}\right. \quad (2)$$

After obtaining the coefficients and constructing the models, projections of endogenous indicators for 2018 were made. To assess the sustainability of a particular country's development, the sustainability indicator was calculated as the geometric mean of the economic sustainability, social sustainability and environmental sustainability coefficients.

6 Conclusion

The sustainability index values of each of the countries for 2018 are presented in Table 1.

Table 1. Sustainability Index for Circumpolar Countries.

	Country	**Sustainability index**
1	Canada	1.127
2	Denmark	1.045
3	Finland	1.219
4	Iceland	1.591
5	Norway	1.492
6	Russia	0.694
7	Sweden	1.246
8	USA	1.081

On the basis of this table, it can be concluded that Norway and Iceland are distinguished by the highest developmental sustainability in 2018, while Sweden, Finland, Canada, the United States, and Denmark are characterised by average sustainability. Russia is characterised by the lowest level of developmental sustainability.

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