

PAPER • OPEN ACCESS

## Analysis of economic development of the Arctic regions of Canada

To cite this article: A Kobylko et al 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **302** 012098

View the [article online](#) for updates and enhancements.

# Analysis of economic development of the Arctic regions of Canada

**A Kobylko, E Kobylko, I Aladyshkin and I Karpovich**

Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia

arinalaz@yandex.ru, eugenekobylko@gmail.com

**Abstract.** The purpose of this article is to create a multi-level (in our case two-level) model that will be able to integrate models of different levels of a single socio-economic system. The multiple model is one of the possible approaches to the analysis of social and economic development of the Arctic region. The main feature of multiple models is that endogenous variables of a lower level are seen as exogenous variables of the following level. The focus of the article is to create a two-level model of the economic growth of the Arctic regions based on the example of Canada. In order to analyse the Arctic territories of Canada it was decided to use a functional approach with the model of autoregressive distributed lags (ADL – model). The general concept of the organization and development management of the Arctic territory of Canada is to represent the Arctic area as a set of target subspaces. For the purpose of target management such subspaces can be united flexibly in a form of an interactive network. This type of representation of the Arctic territory of Canada can be regarded to as subspace approach. This approach was selected as it takes into consideration the complexity and the multi-faceted structure of the research object. The first level of the model is reflected by models of separate target subspaces: territories of fishery; territories of extraction of mineral resources; territories for recreation. The ADL model is selected as a model of assessment for each target subspace. The model of the second level is presented in the form of a system of three equations, depending on the number of target indicators used for the evaluation of a socio-economic system influenced by subspaces. Each equation of the model used for the second level is also presented in the form of the ADL model. The article offers a new technique on how to determine the econometric equations coefficient.

## 1. Introduction

Nowadays the international community is becoming increasingly interested in the Arctic region. The Arctic is often referred to as the strategic regions of the world with the immense natural potential including mineral, fuel, energy and forest resources. However it should not be underestimated that this area is considered to be a severe and dangerous one, and it is covered with a thick snow layer. People are born there, they study at schools, work and later in life become pensioners. A person can be met in all the spheres of the social life in the Arctic space of any circumpolar country. Therefore the study of the various aspects of development in the spheres of social activities of the Arctic circumpolar territories is commonly considered to be of interest.

The purpose of this article is to construct the multilevel (in our case two-level) model combining the models of the Arctic subspaces and the region model. The multilevel model is one of the possible approaches of the analysis of social and economic development of the region of the Arctic territory. The study is based on the usage of institutional and functional approach to the analysis of development of the Arctic territories of Canada, considering them as target subspaces. The main research object in that case is the Arctic territory of Canada that is presented in the form of target Arctic subspaces. The subject of the research is the developments of the target subspaces of Canada.

## 2. Review of literature



The main reason for complexity of modeling and prediction of the dynamics of social and economic systems is their hierarchical character. The model for each level of the hierarchy (including the lowest one – a person) can be constructed very inaccurately. That makes it complicated to develop the exact and reasonable forecast of their functioning (and, therefore, their management). There are many scientific works that are devoted to modeling of systems of that kind. In particular, there is a book devoted to the formation of any hierarchical systems [1]. The book is focused on consideration of a number of mathematical issues that provide an optimal control of similar systems (including dynamic ones), coordination of functioning of various levels, etc. Unfortunately, the application of the results stated in this book (and a number of the publications that take its ideas forward) shows that the problem of identification of the corresponding models based on the available data remains unsolved. Another problem is a possible instability of the model in relation to basic data (when small mistakes in basic data lead to big mistakes in coefficients of model and the forecast of its functioning).

In the book [2] and other scientific works in these two directions it is offered to consider mathematical models of social systems as a limit of stochastic models of the elements comprising them – as it can be done in stochastic mechanics. This approach is considered to be very perspective, however at this stage its practical usage is complicated by the absence of the adequate models of elements (for social systems such elements are supposed to be people). Without identification of structure of the considered systems it is hardly possible to carry out any reasonable forecast of their dynamics and it is also not possible to develop an effective managing strategy. A.Voronin, S. Mishin consider the issue of synthesis and optimization of sistem structure, although the application of their conclusions in real systems is problematic due to the need of identification of the models of the separate elements.

An important approach to the increase of plausibility of social and economic systems modeling is the theory of active systems. According to it the operated subsystem can choose its state proceeding from optimization of the functionality that describes it preferences. It can also build models and forecasts of the operating influences of a higher hierarchy level. The problem of adequacy of the corresponding models rests against an identification problem. It is essential to identify the following issues: systems at the each level of their hierarchy, functionalities, which optimization is defined by their activity, and types of models which are used by subjects in order to describe the environment.

Some authors assume that to overcome these difficulties it is possible to use neural network modeling [3,4].

The review of the studies related to the modeling of territories development showed that such scientists as N. Didenko, D. Skripnyuk, S.V. Kulik, E.S. Romashkina, K.N. Kikkas [5-11] considered the problems of modeling of the development of the Arctic territories and were engaged in studying the problems connected with this issue. In the researches the scientists focused on the features of the development of the Arctic territory of Russia. The wealth, a variety of natural resource and attractive tourist and recreational potential found its reflection in the developed models.

The most advanced synthesis of modeling of a multilevel social and economic system is stated in [7]. The possible consequences are shown in [13,14].

### **3. Representation of the Arctic territory of Canada as a set of target subspaces**

As the Arctic territory of Canada is regarded to be a research object with the complex structure, the general concept of its development organization for mathematical modeling can be represented in the form of a set of target subspaces.

The term "Arctic subspace" can be defined as a part of the area obtaining a number of distinctive properties (attributes), which is characterized by the special purpose of development. These attributes make it possible to carry out a functional division of the Arctic area. Thus, among the possible types of the target subspaces making the Arctic zone of Canada, there were distinguished the following ones:

Areas of production of mineral resources. These territories are understood as locations and industrial facilities built with the purpose of extraction of mineral resources. We are to emphasize that the concept of "the production area of mineral resources" isn't limited only to the definition of the mineral resource deposits. The category of this target subspace does not include explored or proven deposits, which direct excavation and production has not begun so far. Territories of production of mineral raw material resources can also adjoin the basic cities (as in the case of Yellowknife and Whitehorse).

Areas used for recreational purpose. This subspace comprises such places of tourist interest as reserves, national parks, areas for ethno -, eco- and extreme tourism and the other sights of the Arctic region, that all in one form an extensive network of the Arctic tourism. Nowadays such type of tourism is

in the process of development, although the unique features of the Arctic nature provide opportunities to attract visitors not only from the neighboring regions, but also from other states of the country. [12].

However, besides tourist (recreational) function, these subspaces serve for maintaining the natural variety of the Arctic ecosystem.

Areas of fishery. Similarly, as well as in the case with the territories used for mining, this concept isn't limited to the variety of the fish resources available for catching. This target subspace also includes facilities and infrastructure for commercial production of fish products. The Arctic fishery can be seen as a special branch of economy which development demands an extremely careful approach because of fragility of the Arctic ecosystem and its susceptibility to climatic changes.

#### 4. Methodology of mathematical modeling

Description of the model. In order to create a two-level model of the Arctic territory of Canada it is necessary to divide it into two levels. Thorough analysis and creation of each level will allow us to construct a two-level model, which will display the interdependence of socio-economic indexes of each level and demonstrate the influence of socio-economic indexes of a lower level on a higher one. As a basis of division into levels we will take a functional division of the Arctic area of Canada into target subspaces. The first level of the offered model reflects the models of the separate target subspaces: areas of fishery; areas of mineral resource production; areas used for recreational purposes.

As a model of each target subspace it is possible to use the ADL model. Taking into consideration the fact that target subspaces are interconnected in their development, the general model of three subspaces will be presented as a system of the interconnected equations.

The system of the equations of the first level is presented more generally by the following equations (1)-(3).

$$Y_t^1 = \varphi(Y_{t-j}^1; Y_{t-j}^2; X_{t-j}^1 X_{t-j}^2)(1)$$

$$Y_t^2 = \varphi(Y_{t-j}^2; Y_{t-j}^1; X_{t-j}^2 X_{t-j}^3)(2)$$

$$Y_t^3 = \varphi(Y_{t-j}^3; Y_{t-j}^1; X_{t-j}^4 X_{t-j}^5)(3)$$

Let's estimate the Arctic fishery with Avg indicator. GDP by Fishing, % of GDP ( $Y_t^1$ ).

Subspace of the mineral resources production is evaluated with the help of an indicator of Total mining expenditure, Million ( $Y_t^2$ ).

Government expenditure on tourism, % of GDP ( $Y_t^3$ ) is indicative of the subspace used for recreation.

The indicator of Exogenous indicators will be the following variables:  $X_t^1$ - Avg. Number of workers in fishing,  $X_t^2$ - Weekly earnings, dollars,  $X_t^3$ - Avg. Number of workers in mining,  $X_t^4$ - Avg. Number of workers in tourism,  $X_t^5$ - Avg. Total visitors.

The system of equations of the first level with the representation of the each target subspace in the form of an ADL model is shown below (4)

$$\begin{cases} Y_t^1 = a_0 + a_1 Y_{t-j}^1 + a_2 Y_{t-j}^2 + a_3 X_{t-j}^1 + a_4 X_{t-j}^2 \\ Y_t^2 = a_0 + a_1 Y_{t-j}^1 + a_2 Y_{t-j}^2 + a_3 X_{t-j}^2 + a_4 X_{t-j}^3 \\ Y_t^3 = a_0 + a_1 Y_{t-j}^1 + a_2 Y_{t-j}^3 + a_3 X_{t-j}^4 + a_4 X_{t-j}^5 \end{cases} (4)$$

The model of the second level is presented in the form of a system of three equations, i.e. by the number of target indicators which are used for estimation of a social and economic system, influenced by the chosen subspaces. The equations (5) - (7) show the model in general.

$$Z_t^1 = \varphi(Z_{t-j}^1; Z_{t-j}^2; Z_{t-j}^3; Y_{t-j}^1 Y_{t-j}^2)(5)$$

$$Z_t^2 = \varphi(Z_{t-j}^2; Z_{t-j}^1; Y_{t-j}^2; W_{t-j}^1 W_{t-j}^2)(6)$$

$$Z_t^3 = \varphi(Z_{t-j}^3; Z_{t-j}^1; Y_{t-j}^3; W_{t-j}^3 W_{t-j}^4)(7)$$

Representation of each equation from the second level model is done in the form of the ADL model and can be shown by the system of the equations (8).

$$\begin{cases} Z_t^1 = a_0 + a_1 Z_{t-j}^1 + a_2 Z_{t-j}^2 + a_3 Z_{t-j}^3 + a_4 Y_{t-j}^1 + a_5 Y_{t-j}^2 \\ Z_t^2 = a_0 + a_1 Z_{t-j}^2 + a_2 Z_{t-j}^1 + a_3 Y_{t-j}^2 + a_4 W_{t-j}^1 + a_5 W_{t-j}^2 \\ Z_t^3 = a_0 + a_1 Z_{t-j}^3 + a_2 Z_{t-j}^1 + a_3 Y_{t-j}^3 + a_4 W_{t-j}^3 + a_5 W_{t-j}^4 \end{cases} \quad (8)$$

Endogenous indicators for the second level are:  $Z_t^1$ - Avg. GDP, Millions of dollars,  $Z_t^2$ - Avg. Total trade, Millions of dollars USA,  $Z_t^3$ - HDI. Also, the following exogenous indicators were selected:  $W_t^1$ - Cost to export (USD per container),  $W_t^2$ - Cost to import (USD per container),  $W_t^3$ - Public health expenditure, % of GDP,  $W_t^4$ - Crime rate per 100,000 population (all violations).

## 5. Technique econometric model design and coefficients calculation of the econometric system of equations

The following technique was used in order to build the model and to define the coefficients of the equations of the model.

- Formulation of premises and axiomatics of econometric model development: each level of two-level model of any social and economic system is evaluated by the system of indicators (endogenous variables); there is a background of process, i.e. each endogenous variable of the first and second level is influenced by the previous periods; there is a mutual interference of endogenous variables of the first and second level; each endogenous variable of the first and second level is influenced by the internal and external factors (exogenous variables).
- Design of the structural form of the model in general.
- Test of multidimensional time series on stability, using Dickey — Fuller test.
- Test of endogenous and exogenous variables of each equation on multicollinearity on the basis of correlation matrix.
- Choice of lags of an endogenous variable with the strong correlative connection with variable value in the last period and test of the importance of autocorrelation coefficients by means of Ljung-ox Q-test.
- Formulation of a system of equations in a structural form on the basis of the variables analysis, i.e. after the removal of some variables from the analysis.
- Analysis of identifiability of a system of equations and choice of the least-squares method.
- Determination of coefficients of each equation of the model selected by means of the least-squares method.

## 6. Data for the analysis

The collected data refers to the period from 1995 to 2017.

Data sources are: Euromonitor Passport Database, <http://www.euromonitor.com/>; World Bank Open Data, <http://data.worldbank.org/>.

## 7. Approbation of the model

Test of series for stationarity by Dickie-Fuller's test showed that all series are stationary.

In spite of the fact that not all variables passed the test for multicollinearity, it was decided not to exclude them from the further analysis, because of the economic unviability of an exception any variables [12].

Also, all variables successfully passed the test on importance, carried out by means of the Student's test.

As a result of the lags analysis it can be concluded that the majority of variables are the most dependent on the first lag, while the dependence on the third lag is relatively rare.

After the execution of all the stages of the developed technique we were able to receive the coefficients of regression equations. The equations (9) and (10) demonstrate the models that refer to the first and the second level.

The first level:

$$\begin{cases} Y_t^1 = 0,16 + 0,18Y_{t-3}^1 + 9,8E - 06Y_{t-1}^2 - 0,0016X_{t-1}^1 \\ \quad \quad \quad + 0,00032X_{t-1}^2 \\ Y_t^2 = 79,989 - 85,3Y_{t-3}^1 - 0,08Y_{t-1}^2 + 0,76X_{t-1}^2 \\ \quad \quad \quad - 1,95X_{t-1}^3 \\ Y_t^3 = 5,3 + 1,13Y_{t-3}^1 - 0,25Y_{t-1}^3 + 0,0029X_{t-1}^4 \\ \quad \quad \quad - 1,11178325425059E - 06X_{t-1}^5 \end{cases} \quad (9)$$

The second level:

$$\left\{ \begin{array}{l} Z_t^1 = 1251,3 + 0,94Z_{t-1}^1 + 0,539Z_{t-1}^2 - 2873,7Z_{t-1}^3 - 201,46Y_{t-1}^1 \\ \quad \quad \quad + 0,103Y_{t-1}^2 \\ Z_t^2 = 2542,55 - 0,11Z_{t-1}^2 + 0,25Z_{t-1}^1 + 0,0073Y_{t-1}^2 - 0,24W_{t-1}^1 \\ \quad \quad \quad + 0,137W_{t-1}^2 \\ Z_t^3 = 0,857 - 0,048Z_{t-1}^3 - 3,7E - 06Z_{t-1}^1 + \text{Aladyshkin}0,00016Y_{t-3}^3 + 0,005W_{t-1}^3 \\ \quad \quad \quad 7,64E - 07W_{t-1}^4 \end{array} \right.$$

## 8. Conclusion

Analysis of the developed model enables us to make a conclusion, that the target subspaces of the Arctic territory of Canada play an important role in development of the Arctic region, being actually its basis. For implementation of the development concept of the Arctic regions of Canada it is necessary to begin with the development of target subspaces and their related industries.. Definitely it should not be underestimated that the subspaces of the Arctic regions of Canada have a huge potential, connected not only with their development, but also the development of the Arctic in general.

The Subspatial approach used in the study takes into consideration the complex structure of the research object. The Arctic subspaces can be more flexibly united in network of interactions for the purpose of target management.

The program-target approach can be used in order to deal with the global strategic task facing Canada – ensuring sustainable development of the Arctic territories and the organization of their development. Such approach allows to provide cooperation of various participants of the process and also to create conditions for synergetic effect manifestation due to association of the target elements of the Arctic territory development. Therefore, the Arctic subspaces can become the needed target elements of development.

## References

- [1] Mesarović M *et al* 1970 *Theory of Hierarchical Multilevel Systems* p 294 (New York: Academic)
- [2] Helbling D 2010 *Quantitative Sociodynamics. Stochastic Methods and Models of Social Interaction Processes* p 333 (Springer, Berlin, Heidelberg) <https://doi.org/10.1007/978-3-642-11546-2>
- [3] Vasilyev A N and Tarkhov D A 2014 Mathematical Models of Complex Systems on the Basis of Artificial Neural Networks *Nonlinear Phenomena in Complex Systems* **17**(3) p 327–335
- [4] Kainov N U *et al* 2014 Application of neural network modeling to identification and prediction problems in ecology data analysis for metallurgy and welding industry *Nonlinear Phenomena in Complex Systems* **17**(1) p 57–63
- [5] Didenko N I *et al* 2018 Innovative and technological potential of the region and its impact on the social sector development *International Conference on Information Networking: ICOIN* p 611-615
- [6] Didenko N I and Kulik S V 2018 Environmental Shocks: Modelling the Dynamics *IOP Conference Series: Earth and Environmental Science* **180**(1) 012013
- [7] Didenko N *et al* 2017 Modeling the changes in global temperature due to pollution. *International multidisciplinary scientific geoconference surveying geology and mining ecology management SGEM 2017* **17**(53) p 577-586
- [8] Kikkas K N and Kulik S V 2018 Modelling the Effect of Human Activity on Fresh Water Extraction from the Earth's Reserves *IOP Conference Series: Earth and Environmental Science* **180**(1) 012017
- [9] Skripnuk D F and Samylovskaya E A 2018 Human Activity and the Global Temperature of the Planet *IOP Conference Series: Earth and Environmental Science* **180**(1) 012021
- [10] Klochkov Y *et al* 2018 Development of methods for business modeling *International Conference on Infocom Technologies and Unmanned Systems: Trends and Future Directions: ICTUS* p 366-369
- [11] Kireev K V *et al* 2017 Mathematical modeling of Arc extinction process in devices with liquid-metal contact *International Conference on Reliability, Infocom Technologies and Optimization: Trends and Future Directions: ICRITO* p 273-277
- [12] Simone C *et al* 2018 Managing territory and its complexity: a decision-making model based on the viable system approach (VsA) *Land Use Policy* **72** p 493-502
- [13] Didenko N I *et al* 2018 Models of the impact the global crisis has on the world economy *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management: SGEM* **18** p 585-592
- [14] Pogodaeva T V *et al* 2015 Innovations and socio-economic development: Problems of the natural

resources intensive Use regions *Mediterranean Journal of Social Sciences* **6**(1) p 129-135