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The application of the ARCH model for the assessment of transport routes in Northern Europe and Southeast Asia

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The application of the ARCH model for the assessment of transport routes in Northern Europe and Southeast Asia

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Abstract. The article proposes the method of comparison of future transport routes to connect North Europe and Southeast Asia. Two transport routes can pass through the expanses of the Arctic Ocean, along the shores of Russia and Canada. The Southern Sea Route on the Suez Canal and the Trans-Siberian Railway are the alternative transport routes. The Northern Sea Route is the shortest waterway between Northern Europe and Southeast Asia and has many advantages of goods transportation in the future. Compared to the Northwest Route along the Canadian coast, the Northern Sea Route has a greater number of competitive advantages. The authors outline the stages of transport routes comparison method. At the first stage, the goal of the analysis is set and the mathematical model is chosen. The second stage determines the resulting and influential indicators. The third stage involves collecting the information on selected indicators with each indicator being a time series. At the fourth stage, time invariance of each time series is analyzed. At the fifth stage, model is selected that displays the transport corridor. The sixth and seventh stages deal with autocorrelation and multicollinear analysis. At the eighth stage the coefficients of the equations are calculated. At the ninth stage, the conditional variance of the series of the resulting indicator is estimated and the decision is made whether to use the model of autoregressive conditional heteroscedasticity (Arch – Auto Regressive Conditional Heteroscedasticit) for prediction. The paper describes the results of comparison of various international transport routes.

1. Introduction

International transport routes play a significant role in the international trade between Northern Europe and Southeast Asia. They include the Southern Sea Route on the Suez Canal actively used now, future international transport routes through the Arctic Ocean and the Trans-Siberian Railway (Russia). The latter is the longest railway in the world that is about nine thousand three hundred kilometers long. There is also a route from Northern Europe to Southeast Asia around Africa and the route through the Panama or the Nicaraguan Canal.

It is possible to lay two of the most significant international transport routes in the Arctic Ocean - the Northern Sea Route along the shores of Russia and the Northwest Passage along the shores of Canada. They could become an alternative to the South Sea Route through the Suez Canal in the future. The Northern Sea Route is the shortest waterway between Northern Europe and Southeast Asia. The length of the route from Northern Europe across the seas of the Barents, Kara, Laptev, East Siberian, Chukotka and Bering is 7.6 thousand nautical miles. It accounts for 15.7 thousand miles when sailing from Northern Europe to Southeast Asia through the Suez Canal, and 18.3 thousand nautical miles when sailing from Northern Europe to Southeast Asia around Africa. One of the problems of the Northern Sea Route is due to by the fact that ice covers approximately 4.2 thousand nautical miles of the Northern Sea Route. It will take from 15 to 20 days to make this way with an icebreaker. It is appropriate to compare the two options for following the route Rotterdam-Yokohama. The first option, when driving through the Suez Canal and the Indian Ocean, will cover the length of 11.2 thousand miles. The second option implies going along the Northern Sea Route, then the length will be equal to 7.3 thousand miles, which is 3.9 thousand miles shorter. Thus, we reduce travel time by a couple of weeks and save tons of fuel. The Russian Federation sets the rules for navigation on this route, according to the 1982 UN Convention on the Law of the Sea. The legislation of the Russian Federation defines the Northern Sea Route as «the historically established national unified transport communication of Russia in the Arctic».

In terms of economy and geography, the Northern Sea Route is the most important North Russian national transport artery, whose role will significantly increase in the future [1, 2]. The Northern Sea Route is an efficient, safe and reliable way to the natural resources of the Russian North. By the estimates, energy reserves in the Russian North will become the main resource base of the entire planet in the XXI century.

The Northern Sea Route is referred to as a Eurasian international transport route, which has a very large potential for the Russian North. However, ships can move along this path under the following conditions:

a) ships must be certified for ice resistance;

b) convoys of ships should be headed by one of the nuclear icebreakers;

c) there is a set of rules determined by the law of the Russian Federation for navigation along the NSR (Northern Sea Route).

Determined by the role of the Northern Sea Route, the goal is to model some transport routes and to analyze and compare transport routes between Northern Europe and Southeast Asia. The purpose of the article is to discuss the prospects and development trends of the Northern Sea Route. The Northern Sea Route has always been of great interest for professional community and brought up lots of discussions about its prospects and development trends.

2. Literature review

The problem of comparing transport routes is widely discussed in research papers. Thus, the article written by Hong S [3] describes the current status of the Northern Sea Route and the possible benefits from the use of this transport corridor taking into account the evolving natural and economic factors.

The article by Stelpa I. [4] outlines the prospects of making the Northern Sea Route an international transport corridor and the possible benefits of this transformation. Smith L.C. and Stephenson S.R. [5] discuss further prospects for the use of the maritime transport routes in the Arctic, taking into account the ongoing economic, climatic and other changes. Eger M. [6] analyzes the economic component of the use of transport routes in the maritime Arctic, taking into account the ongoing economic, climatic and other changes. The authors of the articles [7–9] dwell on the idea of using the Northern Sea Route for container transportation. To transform the Northern Sea Route into an international transport link it is necessary to modernize and develop transport technologies. Duyzings T. [10] describes the legal component of the Northern Sea Route and defines the legal framework in which the activity takes place.

The Northern Sea Route is often compared with other transport routes. Thus, in [11–13] the authors conduct a comparative analysis of the Northern Sea Route and the Suez Canal in order to identify common approaches to the operation of transport routes. They highlight the advantages of the Northern Sea Route over other routes in Asia-Europe [14].

The authors [15-17] formulate a sequence of actions to minimize the cost of transportation on the Northern Sea Route and develop a model of the efficient transportation options.

3. Methodology of comparing transport routes

This chapter outlines the main stages of the method to compare transport routes.

At the first stage, we set the goal of the analysis, selected the resulting (endogenous) variable and chose international transport routes for this analysis. A mathematical model that describes the relationship between indicators, assesses the degree of development of the routes and compares them is selected after checking the series for time invariance.

At the second stage we determined the indicators. Let us describe this stage on the example of some indicators. We chose transit volume as a resulting indicator. We assume that the volume of transit through transport routes in conditions of increasing intensity of international traffic implies the capacity to maintain international traffic with the available resources and thereby contribute to the economic development. For all conditions, transit volume appears to be the most descriptive indicator to assess the transport route [12]. Other indicators include the following: gross domestic product, i.e. a generalized indicator of national production, the number of ships/vehicles passing through the transport route, i.e. its load intensity and transit capacities, the average cost of passage/transit through the transport route that characterizes its efficiency and the possibility of increasing export revenues of the country of transit.

The third stage consisted in collecting data on selected indicators with each indicator representing a time series. When analyzing time series such indicator as time invariance is of great importance. Therefore, at the fourth stage, we analyze the time invariance of each time series.

The stationary time series is characterized by the following: a) the mathematical expectation of the stationary series $E\left(y_t\right)$ is constant, i.e. the average value of the time series around which the levels change is a constant value; b) the stationary series variance is constant; c) autocovariance of a stationary series with a lag of one time unit is constant, i.e. the covariance between the values x_t and x_{t+1} separated by an interval of one time unit for stationary series depends only on the lag value of one time unit; d) the autocorrelation coefficients of the stationary series with a lag of one time unit are constant. For non-stationary time series that do not conform with these conditions first-order differences were used. We assume that the transformed series were time invariant.

The statistical hypothesis about the time invariance of the process and its differences of increasing order was tested by the Dickey-Fuller method (DF test for a unit root). The method is based on the assumption that a time invariant process has a zero order of integrability with autoregression of type (1).

$$Y_t = \alpha_1 Y_{t-1} + \varepsilon_1 \qquad (1)$$

To check the time series y_t on the integrability order we calculate the value of Studene t-statistics for the parameter δ and compare it with the upper and lower threshold values of the DF statistics. If the value of the calculated t-statistic is smaller (more negative) than the lower critical value for the corresponding number of observations n, the null hypothesis δ = 0 (about the presence of a unit root) should be rejected and an alternative one about the time invariance of the process should be accepted instead. In the case of non-time invariance, the series was brought to time invariance by finding the values of the growth indicators.

At the fourth stage, the autocorrelation coefficients between the rows y_t and y_{t-i} were determined. The time series with an autocorrelation coefficient above 0.7 remained in the model based on the obtained values of the correlation coefficients.

The statistical significance of the correlation coefficients was tested using Student t-criterion.

At the fifth stage, the correlation between all indicators was determined and the correlation coefficient was calculated between the resulting indicator and the influencing factors, i.e. multicollinearity was tested. In the case of a strong correlation between the two factors (the correlation coefficient above 0.8), one of the factors was left in the model, and the other was abandoned. In this case, statistical significance showing the dependence of the factors was checked using Student t–criterion. If the coefficient is insignificant, then the factors are considered independent.

At the sixth stage, we chose the most suitable function for modeling the dependence of transit traffic volume on the influencing parameters in time period t.

We chose the autoregressive distributed lag model (ADL model) which is a time series model with current values depending on both the past values of this time series and the current and past values of other time series. The model with one endogenous variable is as follows (2):

$$Y_t = a_0 + a_1 \bullet y_{t-1} + a_2 \bullet y_{t-i} + b_j \bullet x_{t-j}^k + \Delta \quad (2)$$

The following international transport routes are considered:

1. Southern Sea Route on the Suez Canal.

Influencing parameters (exogenous variables, factors) for the Suez Canal in the time period t are the following: EU GDP, in billion USD - X_1; Number of vessels passing through the canal, in thousand pcs. - X_2; The average cost of passing through the canal, in USD/ton of cargo - X_3; Population of the largest settlements on the way, in thousands of people - X_4.

2. Trans-Siberian Railway.

Influencing parameters (factors) in the time period t are as follows: Russia's GDP, in billion USD - Z_1; The average duration of cargo transportation on the route Korea-Finland, in days - Z_2; Shipping cost, in USD/container - Z_3; The number of containers that passed through Transsib, in pcs - Z_4; Population of the largest settlements on the way, in thousands of people - Z_5.

3. Northern Sea Route.

Influencing parameters (factors) in the time period t are as follows: Russia's GDP, in billion USD - W_1; Number of icebreakers, in pcs - W_2; The minimum ice cover in the Arctic, in million km^2 - W_3; The average cost of passing the canal, in USD/ton of cargo - W_4; Number of ships passing through the canal, in thousand pieces - W_5; Population of the largest settlements on the way, in thousands of people- W_6.

The transit along the Northern Sea Route has been open to foreign companies since 1991, but the first foreign vessel passed through it only in 2009, therefore, the resulting variable for the Northern Sea Route is the total volume of all freight traffic including export, import, transit and domestic traffic.

At the seventh stage, we found the coefficients of the equations using the SPSS-19 regression analysis module. The statistical significance of the equations was checked using the Fisher F-test. The statistical significance of the coefficients was tested using the Student t-criterion.

At the eighth stage, the conditional variance of the series of the resulting indicator was evaluated and the use of the ARCH model was justified. It was decided to use the autoregressive conditional heteroskedaxiality (Arch) model for prediction. At this stage, we stated the problem of the model error. The regression model gives an estimate of the endogenous indicator in the time period y_t with some error *U*. The goal is to estimate the possible value of the error and get a smaller predicted error using the ARCH model. The analysis, which uses the ARCH model, enables us to predict the dispersion of the regression model random component based on its values in previous periods.

In the case of three lags, the ARCH model is as follows (3):

$$U_t^2 = c_0 + c_1 * U_{t-1}^2 + c_2 * U_{t-2}^2 + c_3 * U_{t-3}^2 \quad (3)$$

To check the significance of the ARCH model coefficients, special *CHI* – statistics is used. The assumption is made that the coefficients do not show the dependence expressed in the formula $H_0: \gamma_0, \gamma_1, \gamma_2, \gamma_3 = 0$. Then, we found the coefficients of the Arch-model.

At the next stage, we determined the forecast value for more than two years. Based on the information obtained, we compared the routes and made conclusions.

4. Data

Baseline data (Southern Sea Route):
Sources: http://data.worldbank.org/indicator/NY.GDP.MKTP.CD.
http://www.pancanal.com/esp/plan/estudios/0283.pdf.
http://www.portsaid.gov.eg/magals/ascan/Lists/List8/DispForm.Aspx?ID=1.
http://www.suezcanal.gov.eg/TRstat.aspx?reportId=3.
http://www.suezcanal.gov.eg/TRstat.aspx?reportId=4.
Baseline (Trans-Siberian Railway):
Sources: http://cargo.rzd.ru/static/public/ru?STRUCTURE_ID=51321.
http://data.worldbank.org/indicator/NY.GDP.MKTP.CD.
http://geoconf.ucoz.ru/stati/03/ponomareva.pdf.
http://media.council.gov.ru/files/journalsf/item/20100227141854.pdf.
http://portnews.ru/digest/print/476/?backurl=/digest/.
http://ria.ru/spravka/20130621/944936776.html.
http://www.ati.su/Media/News.aspx?HeadingID=1&ID=12792.
http://www.conteiner.ru/news/111/.
http://www.rg.ru/2011/11/10/reg-dfo/transsib.html.
http://www.rzd_partner.ru/news/different/221050/arma.mephi.ru/.../kan___sergey__germanovich_-_kan_s.g.-8985.doc.
Baseline (Northern Sea Route):
Sources: http://data.worldbank.org/indicator/NY.GDP.MKTP.CD.
http://docs.cntd.ru/document/901949074.
http://nsidc.org/arcticseaicenews/charctic-interactive-sea-ice-graph/.
http://portal.liikennevirasto.fi/sivu/www/north/BIM_Joint_Annual__2001__2012-1.pdf.
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http://www.kolasc.net.ru/russian/innovation/ksc75/6.3.pdf.
http://www.korabel.ru/news/comments/obem_tranzita_gruzov_po_sevmorputi_prevysil_rezultaty_vsego_2012_goda_i_dostig_1_26_mln_tonn.html.
http://www.ibrae.ac.ru/docs/3(7)/74-83.pdf.
http://www.mojgorod.ru/chukotsk_ao/pevek/index.html.

5. Testing methods

The analysis of time invariance of each time series was made. The series appeared to be non-stationary and were transformed into time invariant by finding first order differences.

We used the ADL model for new time invariant series taking into account the number of lags.

The ADL model for the Suez Canal is as follows (4):

$$\Delta y_t = a_0 + a_1 \Delta y_{t-1} + a_2 \Delta x_2 + a_3 \Delta x_3 + a_4 \Delta x_4 \quad (4)$$

The ADL model for the Trans-Siberian Railway has the following form (5):

$$\Delta y_t = a_0 + a_1 \Delta y_{t-1} + a_2 \Delta z_1 + a_3 \Delta z_2 + a_4 \Delta z_3 + a_5 \Delta z_4 + a_6 \Delta z_5 \quad (5)$$

The ADL model for the Northern Sea Route has the following form (6):

$$\Delta y_t = a_0 + a_1 \Delta y_{t-1} + a_2 \Delta y_{t-2} + a_3 \Delta w_1 + a_4 \Delta w_2 + a_5 \Delta w_3 + a_6 \Delta w_4 + a_7 \Delta w_5 + a_8 \Delta w_6 \quad (6)$$

Below are the models after finding the coefficients of the regression equations:

ADL-model for the Suez Canal (7):

$$\Delta y_t = 17{,}88494 - 0{,}09826 \Delta y_{t-1} + 0{,}046584 \Delta x_2 - 42{,}6525 \Delta x_3 + 10{,}07034 \Delta x_4 \quad (7)$$

ADL-model for the Trans-Siberian Railway (8):

$$\Delta y_t = -151754 + 0{,}041397\Delta y_{t-1} + 28{,}27624\Delta z_1 - 60622{,}9\Delta z_2 + 52{,}12283\Delta z_3 - 517{,}53\Delta z_4 + 3663{,}275\Delta z_5 \quad (8)$$

ADL-model for the Northern Sea Route (9):

$$\Delta y_t = -0{,}05993 - 0{,}24304\Delta y_{t-1} + 0{,}303611\Delta y_{t-2} + 0{,}000765\Delta w_1 - 0{,}04654\Delta w_2 - 0{,}06668\Delta w_3 - 0{,}01469\Delta w_4 + 0{,}012029\Delta w_5 + 0{,}010923\Delta w_6 \quad (9)$$

The ARCH model for transport routes will look in the following way.

ARCH model for the Suez Canal (10):

$$U_t^2 = 5{,}67E + 09 - 0{,}1 \cdot U_{t-1}^2 - 0{,}09 \cdot U_{t-2}^2 - 0{,}08 \cdot U_{t-3}^2 \quad (10)$$

ARCH model for the Trans-Siberian Railway (11):

$$U_t^2 = 860{,}95 - 0{,}12 \cdot U_{t-1}^2 - 0{,}22 \cdot U_{t-2}^2 - 0{,}34 \cdot U_{t-3}^2 \quad (11)$$

ARCH model for the Northern Sea Route (12):

$$U_t^2 = 0{,}006 - 0{,}07 \cdot U_{t-1}^2 - 0{,}2 \cdot U_{t-2}^2 - 0{,}3 \cdot U_{t-3}^2 \quad (12)$$

6. Conclusion

According to the obtained results, the indicator of the transit volume through transport routes tends to increase. However, there will be a reduction in the indicator growth in the foreseeable future.

Comparing the increment of values for the Northern Sea Route and the Suez Canal, it should be noted that the values for the Suez Canal are higher, which indicates great prospects for its use. In general, the Suez Canal will be more popular than the Northern Sea Route. Nevertheless, the positive dynamics of the increment values for the Northern Sea Route indicates its prospects as well.

Summing up we can make the following conclusions:

- if current trends of indicator values remain the same the transit value indicator will continue to grow;
- the Suez Canal has more prospects for its development than the Northern Sea Route, which can be explained by the complex climatic and natural risks of the Arctic Ocean, the insufficient infrastructure development of the Northern Sea Route and the difficulties in passing. Maritime container shipping is very important for the development of the region, as evidenced by the growth of transit indicators.

The forecast for 2018–2019 shows a further decline in Transsib and the Southern Sea Route indicator values. At the same time, the indicator values of the Northern Sea Route will grow more intensively in 2020, which proves the increasing importance of this transport route in terms of changing climatic and economic conditions. However, the difficulties in predicting the climatic situation and narrow statistical sampling due to the lack of earlier data and the recent start of operation do not give a comprehensive picture.

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