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Econometric Model for Forecasting Cargo Turnover at Seaports

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ABSTRACT

The seaport, being a complex economic system, meets the needs of a country's economy in sea transportation. Being in close interaction with railway and road transport, seaports take an active part in solving the problem of delivering goods to the end consumer. Seaports also participate in replenishing national budget and develop trade relations of a state, strengthening its status on the world stage. In this regard, forecasting the cargo turnover of the seaport can be considered one of the most important tasks.

The objective of the study is to build and substantiate a model for forecasting the performance of seaports, reflecting the dependence of the cargo turnover of the port industry on the main macroeconomic indicators.

The object of this study refers to Russian domestic seaports. The study has applied methods of analysis, synthesis, content analysis of sources and statistical data, including industry data, for several years, which substantiates the reliability of the results obtained. Constructing an econometric model has been based on the methods of correlation and variance analysis, as well as of least squares.

The novelty of the study refers to the application of a system of recursive equations as a forecast model for the cargo turnover of seaports, where determining factors of cargo turnover, as a result feature, are lagged dependent variables for the previous period.

The developed econometric model can be used for short-term forecasting of cargo turnover in the seaport industry, as well as for assessing its dependence on situation and level of development of foreign economic activity and the entire national economy.

Keywords: port industry, cargo turnover, econometric model, system of recursive equations, autoregression with distributed lags, short-term forecasting.

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BACKGROUND

The functioning of economic systems under the conditions of uncertainty and instability of the external environment has always been considered one of the key problems in the field of strategic planning. In this regard, for several decades many researchers have devoted their works to solving the problem of creating models for forecasting development of both the national and global economies, and of individual business units. For example, the work [1] reflects the issues of constructing models for forecasting economic indicators, without which it is difficult to determine the trajectory of strategic planning of an enterprise. Researchers like V. A. Kryukov and others [2] deal with problematic issues of tools of macroeconomic, interregional and intersectoral analysis and forecasting. However, those models do not consider to full extent the specifics of individual sectors of the national economy, which in some circumstances is one of the most important criteria for selecting a model. In this regard, a model attracts attention proposed by T. L. Samkov, who has revealed the dependence of the forecast of the gross domestic product on the total impact of the volumes and cost of derivatives of exchange transactions on the sale of the most important fuel and energy products and raw materials [3].

The transport industry, notably the maritime transport industry, is of particular importance for development of the domestic economy, as well as domestic and foreign trade, since it meets the needs of the national economy in transportation. Research conducted by a group of authors [4–6] clearly demonstrates the relationship between world trade and sea transport, which justifies the need to build models that make it possible to forecast cargo turnover and, accordingly, plan operation of the transport system depending on key macroeconomic factors. The dependence of maritime trade volumes on development of both the national and global economies is also reflected in the works of many domestic and foreign researchers [7–9].

In this regard, of interest is the research article [10], which is devoted to the issues of constructing logistic models of oil transportation. The analysis of scientific publications devoted to this topic showed a wide variety of approaches and methods used in developing forecasts for development of sea transportation and the cargo portfolio of seaports. For example, Yu. M. Krakovsky and T. Davaanyam are engaged in comprehensive forecasting of basic indicators of the transportation process [11]. In the work [12], a scenario approach is used to forecast the basic indicators of the transportation process. Other authors propose creating hybrid systems of forecasting models, as well as intelligent models, including artificial neural networks [13]. The studies of D. A. Macheret and R. A. Titov are aimed at obtaining results in strategic planning of development of intermodal transport infrastructure [14]. Also, many authors use econometric models to model and forecast the demand for cargo transportation [15] and indicators of exports of goods from the Russian Federation [16]. The features of forecasting multidimensional non-stationary time series using neural modelling are shown in the work [17]. Econometric modelling methods have found wide application in forecasting the development of sea transport in the works of authors worldwide [18–19].

Having summarised the above, the authors set *the objective* of constructing an econometric model that will reflect the dependence of the cargo turnover of seaports on the main macroeconomic indicators characterising the development of the country's economy.

RESEARCH METHODS

The study has resulted in construction of an econometric model of the dependence of seaport cargo turnover on the main macroeconomic indicators characterising the development of the country's economy. Those indicators comprised the volume of industrial production of Russia (IP), the country's foreign trade turnover (FTT), indicators of oil production and export, the industrial production index (IPI), as well as the world price of oil and the volume of world sea cargo transportation.

The information base of this study consisted of data of the Federal State Statistics Service, the Association of Sea Trade Ports, as well as data from the UNCTAD (UN Conference on Trade and Development) for the period from 2000 to 2022. A time interval of 23 years is quite sufficient to obtain reliable modelling results. Table 1 presents the matrix of paired correlation coefficients.

The analysis of the given coefficients of pair and interfactor correlation allowed to identify dependencies between the indicators. A close relationship was established between the cargo turnover of ports and foreign trade turnover, with

Table 1

Matrix of paired correlation coefficients (compiled by the authors)

	Cargo turnover of ports	FTT	World oil price	Volume of sea transportation	Oil production volume	Oil export	IPI	IP
Cargo turnover of ports	1							
FTT	0,78006	1						
World oil price	0,39046	0,61031	1					
Volume of sea transportation	0,98732	0,35628	0,46302	1				
Oil production volume	0,80778	0,79408	0,59408	0,88856	1			
Oil export	0,77895	0,93061	0,91431	0,53733	0,69191	1		
IPI	–0,25629	–0,23199	–0,16080	–0,24581	–0,27402	–0,15166	1	
IP	0,76810	0,87829	0,51883	0,46517	0,89420	0,40410	–0,17434	1

the correlation coefficient was 0,78006; between cargo turnover and the volume of world sea transportation with the closeness of the relationship of 0,93061. At the same time, a strong relationship is clearly traced between foreign trade turnover and the volumes of industrial production and oil exports.

As a result, a system of recursive equations can be preliminarily proposed as an econometric model for forecasting the cargo turnover of seaports which takes the form:

$$Y_1 = f(X_1 X_2), \qquad (1)$$

$$Y_2 = f(Y_1 X_3), \qquad (2)$$

where Y_1 – foreign trade turnover, billion dollars, is considered as a variable dependent (endogenous) on the volume of industrial production and oil exports;

Y_2 – cargo turnover of seaports, million tons, is considered as a variable dependent (endogenous) on the indicator of foreign trade turnover and the volume of world sea transportation.

X_1 – industrial production volume, billion dollars, independent (exogenous) variable;

X_2 – annual volume of oil exports, billion dollars, independent (exogenous) variable;

X_3 – volume of world sea cargo transportation, million tons, independent (exogenous) variable.

As a result, the proposed system of dependencies is a system of recursive equations, in which the endogenous variable Y_2 includes the dependent variable Y_1 as a factor along with the independent variables X_1, X_2 and X_3. Since the initial data are time series, they must be tested for stationarity. In case of a non-stationary time series, it must be reduced to a stationary form by eliminating the cyclical component (if any) from the levels of the series and excluding the trend. Within the system, each equation is considered as an independent regression equation, and its parameters are estimated using the least squares method. The modelling process is accompanied by an assessment of the quality and significance of both the parameters of the resulting model and of the entire econometric model.

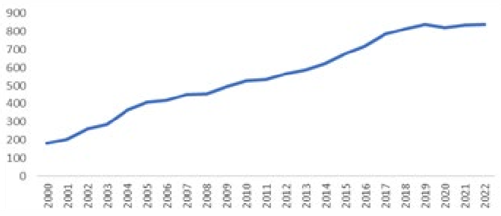
RESEARCH RESULTS

When modelling the relationships of dynamic series, the requirement of their stationarity must be met, i.e., there must be no trend or cyclical fluctuations in them. Visual analysis of the graphs of the initial data presented in Pics. 1–5 as well as determination of the autocorrelation coefficients of the levels of the dynamic series allow us to conclude that there is a trend in all the series under consideration.

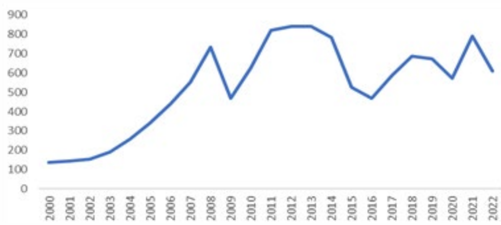
The pictures then show the dynamics of Russia's foreign trade turnover, IP and oil export indicators, as well as the volume of world sea transportation for the period 2000–2022.

The presence of the trend is also confirmed by the autocorrelation functions of the levels of the dynamic series shown in Table 2.

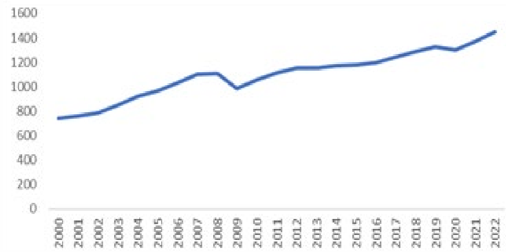
The highest values of the first-order autocorrelation coefficients indicate, first, the presence of a trend in the dynamic series of the indicators under consideration and, second, the absence of periodic fluctuations in them. A trend in the dynamic series may be the reason for the presence of the so-called false correlation between the indicators under consideration. The



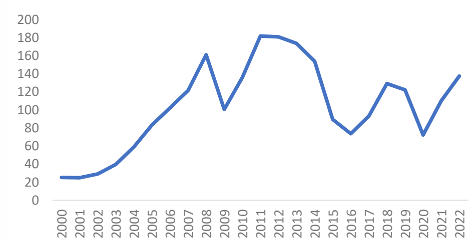
Pic. 1. Dynamics of cargo turnover of Russian seaports for the period 2000–2022 [compiled by the authors based on the data of Maritime News of Russia. [Electronic resource]: https://morvesti.ru. Last accessed 10.10.2023].



Pic. 2. Dynamics of Russia's foreign trade turnover for the period 2000–2022 [compiled by the authors based on the World imports of goods and services: 1970–2023. [Electronic resource]: https://global-finances.ru. Last accessed 10.10.2023].



Pic. 3. Dynamics of industrial production volumes in Russia for the period 2000–2022 [compiled by the authors based on the World imports of goods and services: 1970–2023. [Electronic resource]: https://global-finances.ru. Last accessed 10.10.2023].



Pic. 4. Dynamics of oil export volumes for the period 2000–2022 [compiled by the authors based on the World imports of goods and services: 1970–2023. [Electronic resource]: https://global-finances.ru. Last accessed 10.10.2023].

influence of the time factor will be reflected in the correlation dependence on the values of random errors ε_i, presented in the form of autocorrelation coefficients in the residuals. Therefore, an additional assessment of both the presence and strength of the relationship, as well as the significance and reliability of the obtained modelling results is required.

When constructing the econometric model, the performed check showed that the equations of the system are identifiable. In this regard, the two-step least squares method will be used for the solution in this article. The OLS model [22] was chosen as a model for the dependence of foreign trade turnover on the volumes of industrial production and oil exports:

$$Y_1 = a + b_1X_1 + b_2X_2, \quad (3)$$

where a, b_1 and b_2 are parameters of regression equation.

The model is solved using Microsoft Excel. The parameters and indicators for constructing the OLS model are shown in Table 3.

According to the Student's criterion and Fisher's F-criterion, the calculated values of which exceed their tabulated values, and according to the high value of the determination index, it can be stated that this multiple regression equation reliably describes the dependence of the studied indicators.

Thus, the regression model of the dependence of the foreign trade turnover indicator on the volume of industrial production and oil exports takes the form:

$$Y_1 = -275{,}494 + 0{,}4063X_1 + 3{,}4659X_2 + \varepsilon. \quad (4)$$

The application of the least squares method requires compliance with certain requirements – the assumptions of the least squares method regarding the random variable ε:

Table 2

Autocorrelation functions of time series [compiled by the authors]

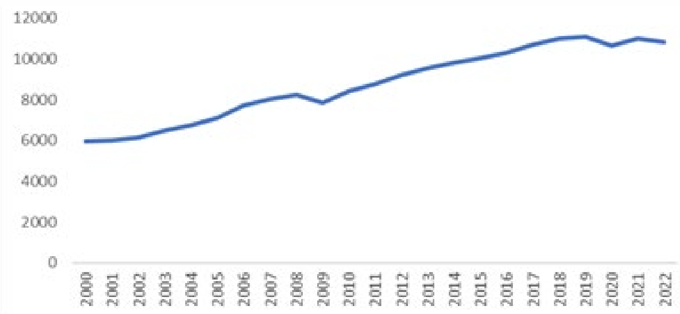
Lag	Autocorrelation coefficients of time series levels				
	Cargo turnover of ports (Y_2)	Foreign trade turnover (Y_1)	Industrial production volume (X_1)	Oil exports (X_2)	World sea transportation (X_3)
1	0,994781	0,833217	0,971767	0,786571	0,989384
2	0,987086	0,694483	0,934653	0,525941	0,978356
3	0,973855	0,577053	0,918512	0,386775	0,965031
4	0,96252	0,435739	0,896265	0,208981	0,96001
5	0,957859	0,304595	0,865891	0,032208	0,958601

Table 3

Parameters and indicators for constructing the OLS model [compiled by the authors]

Correlation analysis					
Multiple correlation coefficient (R)					0,969321
Index of multiple determination (R^2)					0,939583
Adjusted index of multiple determination ($\widehat{R^2}$)					0,933542
Standard error of a variable Y					60,431017
Number of observations					23
Analysis of variance					
	Number of degrees of freedom	*Dispersion*	*Variance per degree of freedom*	*Calculated Fisher F-criterion*	*Calculated significance level of Fisher F- criterion*
Factor regression	2	1135882,596	567941,297	155,519	6,47918E-13
Residual regression	20	73038,157	3651,907		
General regression	22	1208920,753			

Regression analysis				
	Parameters of the regression equation	*Standard error of a variable*	*Calculated Student's t-criterion*	*Calculated significance level of the Student's t- criterion*
Result variable Y_1	–275,493989	75,860589	–3,631582	0,001661791
Factor variable X_1	0,406330	0,082354	4,933921	8,00174E-05
Factor variable X_2	3,465934	0,329692	10,512613	1,35614E-09



Pic. 5. Dynamics of world sea transportation volumes for the period 2000–2022 [compiled by the authors based on the Maritime News of Russia. [Electronic resource]: https://morvesti.ru. Last accessed 10.10.2023].

– randomness of the residuals' fluctuations, which represent a time series of residual sequence levels;

– the mathematical expectation (average value) of the residuals ε_i is zero;

– the residuals of the time series must be homoscedastic, i.e., there should be the same dispersion of ε_i for all variables x_i;

– there must be no autocorrelation in the residuals $\varepsilon_{i;}$

– the distribution of the residuals must obey the normal distribution law.

The data for checking the assumptions of the least squares method are given in Table 4.

Pic. 6 shows a graph of the dependence of random errors ε_i on the calculated $Y_{1(X)}$ for the purpose of testing the first requirement of the least squares method.

Visual analysis of the correlation field of residuals ε_i, which are located within the boundaries of the horizontal line, is the evidence of the randomness of the residual deviations, therefore, the first requirement of the least square method is met: the calculated values of the resulting indicator «foreign trade turnover» well approximate its empirical values.

The second requirement of the least squares method regarding the mathematical expectation of the residuals means that $\sum(Y_i - Y_{i(X)})^2 = 0$. The sum of the residuals for the studied dependence was 2,50111E-12, practically equal to zero, which means the second assumption is rationale.

Table 4

Definition of random residuals ε_i for Y_1 [compiled by the authors]

Obser-vation	Actual Y_i	Theoretical $Y_{1(X)}$	Residuals ε_i	Obser-vation	Actual Y_i	Theoretical $Y_{1(X)}$	Residuals ε_i
1	136,9	111,9642	24,9357	13	842	818,7929	23,2070
2	141,8	119,6901	22,1099	14	842,2	795,4992	46,7008
3	152,9	143,5354	9,36458	15	784,4	734,9523	49,4476
4	191	208,4498	–17,4497	16	526,4	513,0122	13,3877
5	257,1	303,301	–46,2009	17	468,1	466,6123	1,4876
6	340,2	406,9176	–66,7175	18	585,1	552,758	32,3419
7	439,1	497,0251	–57,9251	19	688,1	694,6048	–6,5047
8	551,7	592,066	–40,3659	20	672	688,1707	–16,1707
9	734,7	732,1343	2,5657	21	572,6	504,018	68,5819
10	469	474,2153	–5,2153	22	789,4	662,9137	126,4862
11	625,1	625,4944	–0,3943	23	611	790,6586	–179,6585
12	822,5	806,5141	15,9858	Сумма			2,50111E-12

The third requirement of the least squares method (homoscedasticity of the residuals) is also met, which follows from the same graph shown in Pic. 6. In the graph, the residuals ε_i are located along a straight line (axis $Y_{1(X)}$), which is a clear sign of homoscedasticity.

The fourth assumption of the least squares method is about the absence of autocorrelation of the residuals, i. e., about the absence of dependence between individual levels of the dynamic series of residuals, confirms the consistency and efficiency of the found parameters of the regression equation. Since the construction of the econometric model is carried out based on dynamic series, which, as a rule, contain a trend – this is the dependence of the subsequent level of the dynamic series on the previous one, the fulfilment of this assumption is mandatory when conducting relevant studies. Therefore, two tests for checking the autocorrelation of residuals were used in the work: constructing the autocorrelation function and using the Durbin–Watson test. Using Microsoft Excel, the coefficients of autocorrelation of residuals (autocorrelation function) of the regression equation were calculated, the values of which are given in Table 5.

Low values of the indicators allow us to conclude that there is no autocorrelation of residuals in the considered linear equation of multiple regression.

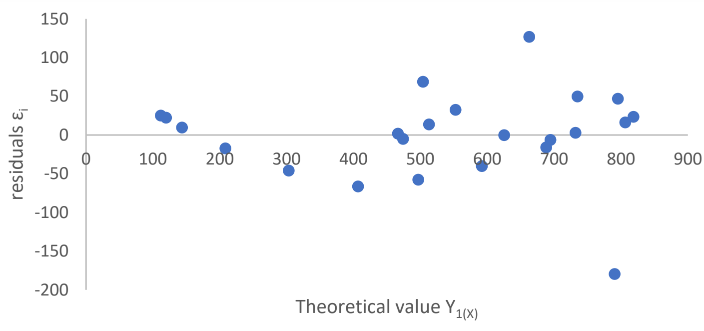
The Durbin–Watson criterion makes it possible to verify the absence of autocorrelation of the residuals. To apply it, the value of d was calculated using the formula:

$$d = \frac{\sum_{t=2}^{n}(\varepsilon_t - \varepsilon_{t-1})^2}{\sum_{t=1}^{n}\varepsilon_t^2} \quad (5)$$

For the calculated multiple regression equation, the actual value of the Durbin–Watson criterion was $d = 40760{,}95/19862{,}86 = 2{,}052$.

Comparison of the calculated value with the critical values allows us to conclude that there is no autocorrelation. Thus, the fourth assumption of the least squares method is confirmed.

In accordance with the fifth assumption of the least squares method, the residuals obey the normal distribution law, which allows us to check



Pic. 6. Graph of dependence of residuals ε_i on $Y_{1(X)}$ [compiled by the authors].

Table 5

Autocorrelation function of residuals Y_1 [compiled by the authors]

Indicator's name	Value
1st order autocorrelation coefficient	–1,8E-05
2nd order autocorrelation coefficient	–0,14941
3rd order autocorrelation coefficient	0,20467
4th order autocorrelation coefficient	0,093643
5th order autocorrelation coefficient	–0,27394

the regression and correlation parameters based on the Student's and Fisher criteria. The constructed regression equation meets the requirements of the fifth assumption (data in Table 3).

The quality of the constructed regression equation is also assessed by the average approximation error – the average deviation of the calculated values $Y_{(Xi)}$ from their actual values Y_i, determined by the formula:

$$A = \frac{1}{n}\sum \frac{\left|Y_i - Y_{(Xi)}\right|}{Y_i}. \qquad (6)$$

For the found regression equation, the average approximation error was 8,45 %, which indicates a good fit of the equation to the initial data.

The obtained results of the evaluation of the regression parameters and correlation indicators together with the entire regression equation are recognised as statistically significant and reliable, and the constructed equation approximates the studied dependence well.

The second stage of constructing the econometric model of recursive regression equations determines the dependence of the cargo turnover of seaports on the indicators of the country's external trade turnover and world sea transportation. A linear multiple regression equation was also used as a dependence model. The obtained modelling results, a preliminary assessment of the regression parameters by Student's *t*-criterion and Fisher F-criterion indicated their statistical significance. Based on the calculated regression equation, the theoretical values of the resulting feature (cargo turnover indicator) were determined, the residuals of the equation were calculated, and the autocorrelation coefficients of the residuals were determined.

But with positive results of the statistical significance assessment, high values of the autocorrelation coefficients were obtained, which indicated the presence of a dependence of the series levels in the residuals, i.e. the presence of autocorrelation of the residuals of the regression equation, which is unacceptable in econometric modelling of the relationships of dynamic series.

In this regard, the authors propose to consider the autoregressive distributed lag model (ADLM) as a dependence model, which allows considering the impact of the levels of dynamic series formed in previous periods. By means of experimental calculations based on a comparative assessment of criterion indicators, the final autoregressive equation is determined, the general form of which is as follows:

$$Y_2 = Y_{2(t-1)} + Y_{1(t-1)} + X_3 + \varepsilon, \qquad (7)$$

where $Y_{2(t-1)}$ – cargo turnover of seaports during the period *t*-1;

$Y_{1(t-1)}$ – foreign trade turnover during the period *t*-1.

The results of calculations and statistical evaluation of the autoregressive equation with a distributed lag are shown in Table 6.

Therefore, the ADLM model for forecasting the cargo turnover of seaports takes the form:

$$Y_2 = -143{,}9483 + 0{,}6495Y_{2(t-1)} + 0{,}0673Y_{1(t-1)} + 0{,}0449X_3 + \varepsilon. \qquad (8)$$

The adequacy of the constructed model of the dependence of the studied indicators is confirmed by checking the significance of the parameters of the regression equation and of the entire equation using the Student's *t*-criterion and the Fisher F-criterion.

The constructed autoregressive equation with distributed lags must also meet the five assumptions of the least squares method. To conduct the check, Table 7 shows the calculation of the residuals of this equation.

The low values of the autocorrelation coefficients given in Table 8 indicate the absence of autocorrelation in the residuals of the constructed autoregressive equation for Y_2.

To test the first assumption of the least squares method, a graph of the dependence of the residuals ε_i on the theoretical values of Y_2 is constructed (Pic. 7).

Visual analysis of the graph allows us to conclude that the first assumption of the least squares method is met. The second assumption (zero average value of residuals) is also justified,

Table 6

Parameters and indicators for constructing the ADLM model [compiled by the authors]

Correlation analysis	
Multiple correlation coefficient (R)	0,996994
Index of multiple determination (R^2)	0,993998
Adjusted index of multiple determination<<Eqn045.eps>>	0,992997
Standard error of a variable Y	16,965676
Number of observations	22

Analysis of variance					
	Number of degrees of freedom	Dispersion	Variance per degree of freedom	Calculated Fisher F-criterion	*Calculated significance level of Fisher F-criterion*
Factor regression	3	858067,220	286022,407	993,705	3,55112E-20
Residual regression	18	5181,015	287,834		
General regression	21	863248,240			

Regression analysis				
	Parameters of the regression equation	Standard error of a variable	*Calculated Student's t-criterion*	Calculated significance level of the Student's t-criterion
Result variable Y_2	–143,948359	59,396017	–2,423535	0,026131
Factor lagged variable $Y_{2(t-1)}$	0,649551	0,101800	6,380610	5,218E-06
Factor lagged variable $Y_{1(t-1)}$	0,067330	0,025066	2,686071	0,015091
Factor variable X_3	0,044959	0,013255	3,391929	0,003249

since the sum of deviations of the theoretical values of Y_2 from its actual levels is almost zero: $\sum(Y_i - Y_{Xi}) = 2{,}558E\text{-}12$.

Fulfilment of the third assumption of the least squares method (homoscedasticity of residuals) is also confirmed by the graph of residuals of the autoregressive equation (Pic. 7).

Based on the data in Table 6, the fifth assumption of the least squares method is verified (the residuals of the autoregressive equation obey the normal distribution law), which is confirmed by testing according to the Student's *t*-criterion and Fisher F-criterion.

For the autoregressive equation, the average approximation error was also calculated, which amounted to 2,9 %, which indicates a good quality of the selected model of the studied dependence.

As a result of the study, the econometric model for forecasting the cargo base of seaports can be represented by the following system of recursive equations:

Table 7

Definition of random residuals ε_i for Y_2 [compiled by the authors]

Observation	Actual Y_i	Thteoretical Y_{Xi}	Residuals ε_i	Observation	Actual Y_i	Theoretical Y_{Xi}	Residuals ε_i
1	203,7	235,5762	–31,8763	13	589	595,9448	–6,9448
2	260,8	253,5400	7,2599	14	623,4	628,3191	–4,9191
3	286	303,9349	–17,9349	15	676,7	677,2517	–0,5517
4	364	328,3520	35,6479	16	721,9	726,8583	–4,9583
5	406,9	389,2027	17,6972	17	787	766,6391	20,3608
6	421	436,9808	–15,9808	18	816,5	814,9832	1,5167
7	451	453,5747	–2,5747	19	840,3	839,3204	0,9795
8	454,6	469,5070	–14,9070	20	820,8	842,4992	–21,6992
9	496,4	473,0549	23,3450	21	835,2	830,6121	4,5878
10	525,9	514,4688	11,4311	22	841,5	845,0535	–3,5535
11	535,4	537,1996	–1,7996				
12	565,5	560,6258	4,8741	Sum			2,558E-12

Table 8

Autocorrelation function of residuals Y2 [compiled by the authors]

Indicator's name	Value
1st order autocorrelation function	–0,1927
2nd order autocorrelation function	–0,0028
3rd order autocorrelation function	–0,07455
4th order autocorrelation function	–0,0523
5th order autocorrelation function	0,066453

$Y_1 = -275{,}494 + 0{,}4063X_1 +$
$+ 3{,}4659X_2 + \varepsilon,$ (10)
$Y_2 = -143{,}9483 + 0{,}6495Y_{2(t-1)} +$
$0{,}0673Y_{1(t-1)} + 0{,}0449X_3 + \varepsilon.$ (11)

In accordance with the economic interpretation of the parameters of the regression equation, the following relationship was established between the indicators of the first equation of the system: an increase in the volume of industrial production of the country by 1 billion dollars leads to an increase in foreign trade turnover by an average of 0,4063 billion dollars per year; an annual increase in oil exports by 1 billion dollars provides an average annual absolute increase in foreign trade turnover of 3,4659 billion dollars.

The presence of an autoregressive equation with lagged variables in the system means the dependence of the resulting feature on the previous values of the factor variables of the model, expressed in the values of the regression coefficients:

– the cargo turnover of seaports will increase on average per year by 649,5 thousand tons under the influence of its own growth in the immediately preceding year by 1 million tons;

– the annual growth of the country's foreign trade turnover by 1 billion dollars at time (t – 1) provides an average absolute increase in the cargo turnover of seaports in the following year in the amount of 67,3 thousand tons;

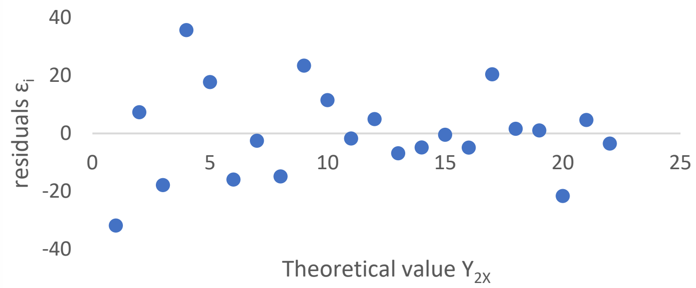
– the growth of world cargo transportation by 1 million tons per year has a positive effect on the volume of cargo handling in Russian ports, increasing them by an average of 44,9 thousand tons.

CONCLUSION

The study analysed the dynamics of cargo turnover at Russian seaports, key macroeconomic indicators (volumes of foreign trade turnover and industrial production, oil exports and volumes of global cargo transportation) and identified the relationships between them for the period from 2000 to 2022. Based on the data obtained, the main factors determining the volume of cargo turnover were identified, and an econometric model for forecasting the cargo turnover of Russian seaports was developed, which is a system of recursive equations. A distinctive feature of the model is that it allows not only to present a short-term forecast of the cargo turnover of seaports, but also to assess the dependence of the port industry on the state of the national economy and its foreign economic activity.

The resulting econometric model was assessed for the closeness of the relationship between the indicators, the significance and reliability of the regression parameters and of the entire regression equations. Besides, the model was tested for compliance with the assumptions of the least squares method, which also confirmed the good quality of the constructed model.

The practical application of the presented model will allow, based on the forecast of the



Pic. 7. Graph of dependence of residuals ε_i on Y_{2X} [compiled by the authors].

cargo portfolio, to solve such problems as replenishment of the merchant fleet, rationale of the relevance of investment in the main production assets of the port infrastructure. Based on the data obtained, a unique opportunity is provided to make strategically important decisions for the industry and the country's economy regarding the transit capacity of the coastal component, the use of port capacities, as well as forecasting the employment of labour resources, which will allow timely preventive measures to be taken if such a need arises.

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