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Larin S., Loginova D. Econometric modeling of the development of helicopter industry enterprises taking into account the innovation factor

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Abstract. *Over the past decade, the Russian helicopter industry, which has been characterized by steady growth, has been confronted with difficulties caused by unstable political situation, fierce competition in world markets, rapid development and introduction of innovative technologies in this sector of the Russian economy. In order to maintain their position in the global market and increase the competitiveness of their products, Russian companies must adapt production to the changing demand for helicopters and pay increased attention to supporting the technological support of production with the latest materials, equipment and components of domestic production. The purpose of this study is to analyze the current state of the enterprises of the domestic helicopter industry on the example of the holding "Helicopters of Russia". To achieve this, the econometric package EViews10 was used and linear and nonlinear models were built, allowing to evaluate the existing and promising demand for Russian helicopters. As a result of the analysis of the models, factors that have a significant impact on the production of Russian helicopters were identified.*

Keywords: *Russian economy, helicopter industry, Russian Helicopters holding, helicopter demand, modeling, tools, EViews10.*

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Introduction

In order to preserve competitive ability at both world and home markets national enterprises, referred to the helicopter industry, should concentrate its efforts on the hold of such market niches, where it already have got a certain share, as well as on its expansion due to the improvement of the quality of the manufactured production. In the short term is expected the growth of the competition at both global and home markets due to the quick growth of the quantity and quality of offered products /services, technologic innovations, the number of mergers and takeovers of enterprises under the influence of permanently changing market conditions.

Since the helicopter industry has been formed as a branch, considerable changes were taking place in the organization of its production. So, for example, the helicopter industry in USSR has been building medium and heavy machines (mainly for the military sector). Since 2010 there is such a trend in Russia as the transition to the manufacturing of light helicopters (for the civil aviation). Anyway, due to the experience, accumulated for a long time just in the medium and heavy segment, Russian helicopter

building companies are world leaders. Today Russian enterprises manufacture such unique samples as: multi-purpose all-weather combat helicopter Ka-52 Alligator; Ми-35M – combat helicopter, which can also be used for civil purposes; radar surveillance helicopter, ship-based helicopter Ka-31 and many others. Only the Russian Ми-26 remains the only sample, able to lift cargos, weighing up to 20 tons [9].

It should be highlighted that both the technologic and innovative components play a determining role in the development of the helicopter industry in Russia. Annually the spectrum of manufactured samples is being modernized and the manufacturing of absolutely new ones is being expanded. For example, in 2023 is expected the launch of the industrial production of the future commercial helicopter ПКВ, and since 2024 will be started first sales of unscrewed aerial vehicles БАС-500-750.

Russian companies release 35% of the world park of combat helicopters and about 17% of the world park of ultra-heavy helicopters, as well as 56% of the world park of medium helicopters [9], in the light helicopter industry the Russian production is less spread. The competitive ability of the helicopter industry of the RF requires the model range correction [1].

Research purpose

The basic purpose of the research hereunder was the analysis of the innovative development of the helicopter industry of Russia at the example of the “Helicopters of Russia” holding. In this juncture was performed the econometric research, involving the range of the statistic data of the AO “Helicopters of Russia” holding for the period of 2008 - 2017.

Materials and Methods

Since 2007 the development, the production and the technical maintenance in the field of the modern civil and military helicopter industry is carried out by Rostechnologii State Corporation, namely by its affiliated company – AO Helicopters of Russia. The holding has been created by means of the consolidation of strategic stakes of all helicopter building plants, existing at that moment in Russia. AO Helicopters of Russia comprises 23 enterprises, anyway, only 2 representatives of the holding have achieved the world level and are investing in R&D – AO M.L. Mil Helicopter Plant and AO Kamov [2, 12].

The key of Helicopters of Russia is to satisfy the domestic demand for civil and military helicopters. To insignificant moments in its performance are referred the maintenance of the competitive ability of the domestic manufacturer, the implementation of import substitution programs, the preservation of stable positions at world markets and the permanent upgrading of production technologies.

The holding supplies its production mainly to national customers, namely to the Defense Ministry of Russia, MES of Russia, MIA of Russia, Gazprom avia and UTair airlines, as well as to other consumers. Many consumers of Helicopters of Russia are also located abroad. For example, two years ago the company has implemented the order for the supply of 151 helicopters for India, was executed the contract for the supply of 7 rescue (Ka-32A11BC) and 2 multi-purpose helicopters to the PRC, separately was

concluded the contract for the supply of 18 units for the Chinese company Wuhan Rand Aviation Technology Service etc. Nowadays more than 8500 helicopters, of different brands made in Russia are used in more than 100 world countries [9].

Figures 1 and 2 show, that the gain of the Russian holding AO Helicopters of Russia, as well as volumes of deliveries of helicopters are characterized by stable development indices. The growth of supplies for the period hereunder took place mainly due to the growing demand for the military aviation in developing countries, growing sales of spare parts and the promotion of the maintenance service.

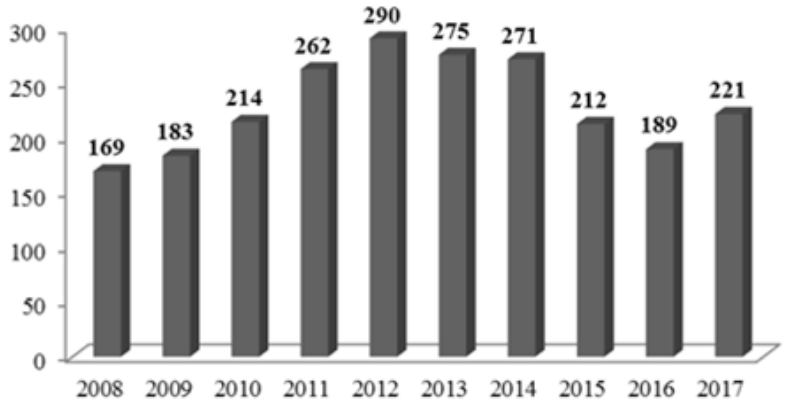

Figure 1. Number of supplies of helicopters in 2008-2017, pcs.
Source: drafted by authors.

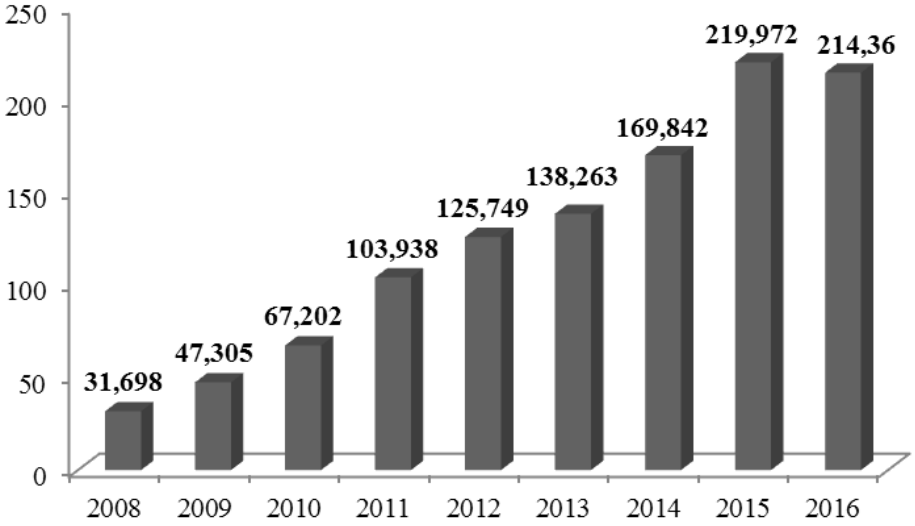

Figure 2. Gain of Helicopters Russia holding in 2008-2016, bln. rub.
Source: drafted by authors.

Due to the stable character of the demand of Russian-made helicopters this segment of the aviation branch of the region did not encounter large scale interruptions. The obvious shift to light helicopters became one of last trends of the development of the Russian helicopter park. The stable position of the Russian holding is referred to the growth of the number of exported military helicopters of Ми-8/17 series, which different modifications will remain popular both in our country, as well as in different world countries for minimum 30 years at least [14]. For example, African countries operate about 600 units of Ми-8/17 type. The park of these helicopters in the Latin America

comprises more than 400 units. At these continents Russian-made helicopters almost do not have alternatives, first of all due to the harsh climate. Today of more than 12 thousand of Russian made helicopters only 3 thousand units are being operated outside of Russia and CIS countries [13]. Nowadays the enterprise is being actively developing new prospective models of such helicopters as Ми-38, Ansat and RACHEL [10].

For the purpose of the analysis of the innovative development of helicopter industry enterprises of Russia was performed the econometric research of AO Helicopters of Russia. As input data is used the statistic data of the company for the period of 2008 - 2017. On the basis of the revealed dependence between the input and the output information was performed the analysis and were revealed factors, considerably influencing the enterprise development, problems were revealed and options for its solution have been offered.

For the research the specialized EViews program was used, which is one of popular econometric packages. It allows to carry out the analysis of the current data and to forecast prospects of the enterprise development for the short-term. The program functional allows to establish the statistic link between selected data packages and then to use this link for the forecasting of future values of development indices.

Within research frames was performed the modeling of processes of the influence of internal factors on the innovative development of AO Helicopters Russia. So as interpretable variable Y was selected the index, demonstrating the level of the technologic development of the enterprise and of the demand for the manufactured production – number of supplies of helicopters by the holding Helicopters of Russia. To factors, influencing the dependent variable, referred: the size of the state defense order, X1; service expenses, X2; expenses on capital investments, X3 [2-9].

Results and Discussion

Before the modeling it is necessary to analyze statistic indices, otherwise called descriptive statistics, characterizing the set of data and measuring its features (see fig. 3) [15].

	Y	X1	X2	X3
Mean	228.6000	69.80000	13.29960	31.72590
Median	217.5000	60.00000	14.95000	29.59650
Maximum	290.0000	127.0000	20.60000	55.41600
Minimum	169.0000	25.00000	2.290000	7.543000
Std. Dev.	42.92422	34.35695	6.458570	18.05615
Skewness	0.100858	0.398523	-0.558143	0.076237
Kurtosis	1.558306	2.243448	1.921531	1.652883
Jarque-Bera	0.882988	0.503189	1.003829	0.765822
Probability	0.643075	0.777560	0.605371	0.681874
Sum	2286.000	698.0000	132.9960	317.2590
Sum Sq. Dev.	16582.40	10623.60	375.4181	2934.222
Observations	10	10	10	10

Figure 3. Results of the calculation of the component of descriptive statistics

Source: composed by authors

Results of the calculation of the component of the descriptive statistics showed that the average amount of manufactured helicopters in the period of 2008 - 2017 (Y) was 229 units, the average size of the state defense order (X1) is equal to 70 helicopters, the average value of services' expenses (X2) is 13,3 bln. rub., the average value of capital expenses (X3) is 31,7 bln. rub.

The analysis of obtained results showed that the enterprise development in many ways depends on the number of helicopters, manufactured for needs of RF Ministries. This conclusion is confirmed by the pair correlation matrix (see fig. 4). The highest value r_{yx1} = 0,87 has got the pair linear correlation matrix between the dependent variable and the X1 factor (size of the state defense order). Meanwhile, considered factors are correlatable, what confirms the multicollinearity in the model. The strongest link is between the index X2 (service expenses) and the index X3 (capital expenses) (r_{x2x3}=0,89). Other links between factors are weak. Maximal expenses on the technical upgrading and R&D were 55,4 bln. rub.

	y	*x1*	*x2*	*x3*
y	1			
x1	0,866831	1		
x2	0,504526	0,453203	1	
x3	0,161972	0,262025	0,890043	1

Figure 4. Matrix of pair correlations.

Source: drafted by authors

Among characteristics of descriptive statistics (see fig.3) there is Jarque-Bera statistics, aiding to the check the zero hypothesis on the normality of distribution of considered random values. As p-values of independent variables exceed 0,05 and 0,1 (for 5% and 10% confidence levels), the zero hypothesis of the normality of distribution is accepted.

With use of possibilities of EViews program was built the linear model of dependence of the number of Y helicopters, manufactured by Helicopters of Russia holding, from internal factors – the size of X1 state order, service expenses X2, capital investments X3.

As it shows from results of the evaluation of the linear equation, given at the fig. 5, the equation has go a statistic value (Fstat=27,4 p-value=0,000). The determination coefficient R2=0,9319 shows that 93,19% of the total variation of the dependent variable (i.e. the spread of its values around the mean one) is represented by the variation of the independent variable.

The obtained value of regression coefficients b_1=0,7923; b_2=7,0629 and b_3=–2,2585 can be interpreted as follows: all things equal the increase of the index: the increase of the state order (X1) amount by 1 unit causes the average increase of supplies of helicopters by 1 unit per year; the increase of service expenses (X2) by 1 bln. rub. causes the average increase of supplies of helicopters by 7 units per year; the increase of capital expenses (X3) by 1 bln. rub. cause the average decrease of supplies by 2 units

per year.

So, the required equation can be represented this way (1):

$$Y^{\wedge} = 151{,}0192 + 0{,}7923 \times X1 + 7{,}06296 \times X2 - 2{,}2585 \times X3 \quad (1)$$

Sample: 2008 2017
Included observations: 10

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X1	0.792270	0.159167	4.977615	0.0025
X2	7.062962	1.792413	3.940477	0.0076
X3	-2.258541	0.592203	-3.813795	0.0088
C	151.0192	11.86247	12.73084	0.0000

R-squared	0.931981	Mean dependent var	228.6000
Adjusted R-squared	0.897972	S.D. dependent var	42.92422
S.E. of regression	13.71080	Akaike info criterion	8.363420
Sum squared resid	1127.917	Schwarz criterion	8.484454
Log likelihood	-37.81710	Hannan-Quinn criter.	8.230646
F-statistic	27.40358	Durbin-Watson stat	3.177617
Prob(F-statistic)	0.000671		

Figure 5. Evaluation of the linear equation

Source: drafted by authors with use of EViews.

The signification of the obtained equation and of evaluations of coefficients of the linear model of the multiple regression with three independent factors allows to use it for the obtaining of estimates of the number of helicopter's supplies.

As it shows from the figure 6, the confidence interval of the estimated value of the dependent variable is rather narrow, which indicates the high quality of the evaluation of the equation of the linear multiple regression with three factors. The Theil coefficient is 0,02. The relative approximation error is 3,27%, what means the good precision of estimated values and the deviation of estimated values from actual ones can be recognized as minor. The adequacy of the obtained linear model of the multiple regression with three independent factors allows to use it for the more detailed analysis of the dependence of the innovative development of AO Helicopters of Russia from the range of other factors.

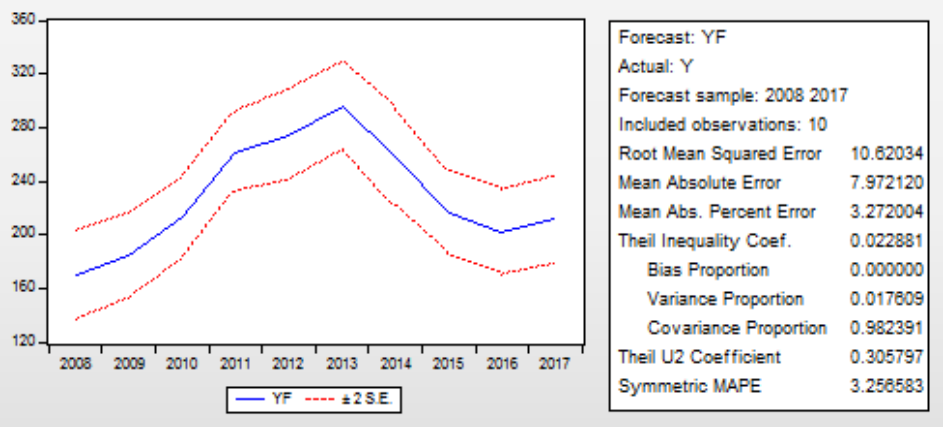

Figure 6. Estimated values and the confidence interval of the dependent variable in the linear model.

Source: drafted by authors with use of EViews.

In order to reveal the most adequate model we will additionally build the non-

linear model and compare results, obtained with its use, with results, obtained at the linear model. Results of the evaluation of the logarithmic are given at the figure 7. The equation is major in whole (Fstat=14,997, p-value=0,003), coefficients at factors X1 and X3 are major at 5% level of majority, X2 – at 10% level.

Sample: 2008 2017
Included observations: 10

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(X1)	0.256088	0.072762	3.519523	0.0125
LOG(X2)	0.301701	0.129351	2.332428	0.0584
LOG(X3)	-0.299344	0.115633	-2.588747	0.0413
C	4.609898	0.270290	17.05535	0.0000

R-squared	0.882333	Mean dependent var	5.415897
Adjusted R-squared	0.823500	S.D. dependent var	0.189687
S.E. of regression	0.079691	Akaike info criterion	-1.932144
Sum squared resid	0.038104	Schwarz criterion	-1.811110
Log likelihood	13.66072	Hannan-Quinn criter.	-2.064918
F-statistic	14.99717	Durbin-Watson stat	2.583681
Prob(F-statistic)	0.003403		

Figure 7. Results of the evaluation of the non-linear equation.
Source: drafted by authors with use of EViews.

The obtained value of regression coefficients b_1=0,26, b_2=0,3 и b_3=–0,299 can be interpreted as follows: all other things being equal the increase of the state defense order (X1) by 1% causes the growth of the number of supplied helicopters by 0,26% per year, the growing of services (X2) by 1% causes in the mean the increase of manufactured helicopters by 0,3% per year, as well as the increase of capital expenses (X3) by 1% causes the decrease of supplies of helicopters by 0,299% per year.

So, we can provide the required equation (2):

$$\log(Y) = 4{,}06 + 0{,}256 \times \log(X1) + 0{,}30 \times \log(X2) - 0{,}299 \times \log(X3) \quad (2)$$

Let's compare obtained characteristics of both linear and non-linear multiple regression models (see fig. 8).

Forecast: YF	
Actual: Y	
Forecast sample: 2008 2017	
Included observations: 10	
Root Mean Squared Error	10.62034
Mean Absolute Error	7.972120
Mean Abs. Percent Error	3.272004
Theil Inequality Coef.	0.022881
Bias Proportion	0.000000
Variance Proportion	0.017609
Covariance Proportion	0.982391
Theil U2 Coefficient	0.305797
Symmetric MAPE	3.256583

Forecast: YF	
Actual: Y	
Forecast sample: 2008 2017	
Included observations: 10	
Root Mean Squared Error	14.79511
Mean Absolute Error	12.09446
Mean Abs. Percent Error	5.175719
Theil Inequality Coef.	0.031927
Bias Proportion	0.001021
Variance Proportion	0.045077
Covariance Proportion	0.953903
Theil U2 Coefficient	0.431882
Symmetric MAPE	5.197931

Figure 8. Comparison of both the linear and non-linear models.
Source: drafted by authors with use of EViews.

In the non-linear equation (2) the average approximation mistake was 5,17%, while in the linear model this index was lower than 3,27%.

The root mean square error of the estimated value is 14,795; the average mistake module is 12,094; the Theil coefficient is 0,031. So, in order to determine the most precise model it is necessary to compare these indices according to both linear and logarithmic models. So, the root mean square error of the estimated value in the linear model is 10,62, the average value of the error value is 7,97, and the Theil coefficient is 0,022. The less is the data on mistakes and the closer is the Theil value to the zero the higher is the evaluation quality. The comparison of models' indices shows that quality evaluation indices for the linear model of the multiple regression exceed equivalent indices for the logarithmic model.

The obtained opinion is confirmed by:

- the deviation of the average estimated value Y from the average observed value Y (in the linear model it is equal to 0,000, in the logarithmic one it is 0,001);

- the deviation of the mean square deviation of the estimated Y from the mean square deviation of the observed Y (0,0176 and 0,045 accordingly);

- the random forecast error (0,982 – in the linear and 0,954 – in the logarithmic one).

In this case in the determination of models' quality we are basing on the following logic: the closer are values of first two indices to the zero and of the latter to the unity, the higher is the model evaluation. So, we can make a conclusion that the linear model is more adequate and it should be used in the following research.

While continuing the study of the required equation (1) let's use the Darbin-Whatson test [16]. In order to reveal the auto-correlation is proposed the theory on the absence of the residual autocorrelation. Alternate hypotheses – about the positive or negative residual autocorrelation. As it shows from the evaluation of the equation, given on the figure 5, DW=3,18. With the number of observations n=10 and 3 regressors the upper border of Darbin-Whatson statistics has got at the 5% significance level is equal to 2,016 [16], but does not achieve 3,45, what shows the absence of grounds to reject the hypothesis. So there is no autocorrelation.

Conclusion

Models, built by us, as well as performed calculations, allow to assert that such both external and internal factors as the size of the state defense order, service expenses and investments to the main capital considerably influence both the production and innovative development of the Russian helicopter industry. It also should be highlighted that notwithstanding the decreasing demand for the production AO Helicopters of Russia steadily continue its activities. Sanction restrictions still restrain considerably its presence at world markets. Provided that Russian helicopters plan to occupy 20% of the world helicopter market till 2025 [11], the creation of the relevant infrastructure for the maintenance of its production all other the world is a high priority task. So, Russia develops partnership relations with other countries, ruling huge parks of home-made helicopters, and aim to develop the necessary potential in the technical maintenance, repair and technical inspection in its territories.

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