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THE MODELING OF THE MACHINE-BUILDING COMPLEX DEVELOPMENT OF THE REPUBLIC OF BELARUS

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Machine-building complex of the Republic of Belarus plays a special role in the country's industry. This article is devoted to the construction of predictive models of growth of the machine-building complex of the Republic of Belarus on the basis of factors, which directly affect it. While writing the article, the author has used such tools as PEST-analysis, correlation analysis, graphical analysis and modeling.

Key words: machine-building complex, modeling, growth rate, correlation matrix, PEST-analysis, graphic analysis.

Introduction. Machine-building complex of the Republic of Belarus occupies a special place in the industry of the Republic of Belarus. More than 60% of Belarusian machine-building products are sold abroad. Experts predict in the medium term growth of demand of Belarusian engineering products in Russia and Kazakhstan, which together account for about 73% of Belarusian engineering exports. Experts note that good prospects for the export of these goods create prerequisites for the overall development of the industry in the country [1].

An important role in the formation of the machine-building complex of Belarus has played its scientific and technical potential (research, design organizations, pilot production). The main links of this complex were the automotive industry, tractor and agricultural machinery production, machine tool construction, electrical and radio engineering industry, instrument making, production of electronic and computer equipment. A significant place was occupied by the production of the military-industrial complex [2]. Thus, the study and forecast of the development of the machine-building complex is very important.

Results and its discussion. To select independent variables for modeling, the author has used such tools as PEST analysis and correlation matrix. To build the models, the has chosen the indicators, which characterize the development of mechanical engineering since 2004 until 2004-2017 (14 years) years, because this period is characterized by relative stability of development, the absence of sharp fluctuations (the average annual chain growth rate of mechanical engineering is 132,319%), as well as a relatively favorable environment for strengthening the position of the machine-building complex and the growth of its competitiveness, which is expressed in the presence of strong support from the state, regular investment revenues, the development of innovative approaches to the management of product sales, etc.

In the models, the dependent variable Y is the chain growth rate of production of machinery, vehicles and equipment, because this indicator most fully reflects the dynamics of the engineering industry.Also, based on the opinions of experts and economists, independent

variables (X1,..Xn), which reflect the factors directly influencing the development of the machine-building industry "(see "table 1 - PEST analysis of the machine-building industry")". These are such variables as, growth rate of investments in fixed capital,% (X1); growth rate of economically active population,% (X2); growth rate of initial cost of fixed assets,% (X3); growth rate of real wages of workers,% (X4); growth rate of the index of prices of producers of industrial products, % (X5); the growth rate of total costs of environmental protection,% (X6); the growth rate of internal costs of research and development, % (X7); the growth rate of the volume of research, % (X8); the growth rate of costs of industrial organizations for technological innovation, % (X9); the growth rate of the number of organizations performing research and development, units,% (X10).

Table 1 – PEST analysis of the machine-building industry of Republic of Belarus

Political factors	Economic factors
1. The high level of government support of the industry (tax benefits, customs benefits, direct government financing, inclusion in the government procurement programme); 2. The creation of the Common economic space leads to a reduction in costs of trade between the countries included in it, and the emergence of new opportunities for cooperation; also, the common customs tariff creates barriers for foreign suppliers of engineering products, increasing the demand for import-substituting products of enterprises of the Bank's member States; 3.After Russia's accession to the WTO, measures to jointly create regulations for scientific and technical activities of machine builders of the Union state and the CES continue. In particular, the Joint Institute of mechanical engineering of the NAS of Belarus is developing new national standards, which in the framework of the formation of a unified system of technical regulation and standardization of the SES should be consistent with international standards; 4. Increased competition among manufacturers in the Russian market of both Russian origin and foreign production; 5.Globalization of the world market of mechanical engineering in the form of large production giants with a full production base (chain) and huge sales opportunities; 6. Strengthening of intercultural conflicts in the middle East.	1.The obvious advantage is used by manufacturers that combine high quality machines at the best price; 2.Strong dependence on the macroeconomic situation in Belarus and Russia as the largest consumer of Belarusian engineering products; 3. The emphasis on the use of preferential public financing of large machine-building enterprises has led to problems with the renewal of production assets of medium and small enterprises in the industry, which were not available investment resources of both public and private sectors; 4. Sharp fluctuations in the national currency; 5.Chronic foreign trade deficit and current account deficit; 6.Wages are set by the government regardless of the profitability of organizations and their economic results; 7.Global economic crisis; 8.Strong emphasis on the production of quality import-substituting products and ignoring the fact of future significant costs for the promotion of products and efforts to " win " the client; 9. Reduced economic growth in Russia, tougher competition (due to Russia's accession to the world trade organization), as well as Russia's transition to the new environmental standard Euro-5, Euro-6 (in 2020).

Ending of the table 1

Social factors	Technological factors
1. The global consumer has become more demanding, forcing producers to produce diversified products; 2. Special requirements are imposed by consumers to reliability and resource; 3. Loss of the target audience of engineering products of the middle and lower-middle price segment (development of effective demand and transition of the main consumers to a more expensive price segment).	1. The limitations of own raw material base; 2. High prices for fuel and energy resources (TER)); 3. Due to the orientation of domestic products mainly on the Russian market, the prospects for the development of the Belarusian machine-building complex in the medium term will be determined by the level of competitiveness compared to similar Russian enterprises; 4. Depreciation policy of Belarus has a predominantly tactical focus, i.e. it focuses on the implementation of the ongoing tasks that ensure survival in a crisis or solve the problem of preservation of business in General (solving the problem of permanent lack of working capital and reduction of production costs). Therefore, the depreciation policy is not progressive, as it is its strategic purpose, aimed at solving long-term problems of innovative orientation, associated with the timely technical re-equipment of production and the creation of competitive products, is practically not developed and not developed. As a result, such tactics dooms mechanical engineering to technological dependence on foreign suppliers of production equipment and technologies; 5. Machine-building industry needs constant innovative development for successful functioning.

Source: authors' self-development

Thus, as it has been rightly stated in the monograph prepared by the team of authors under the guidance of the famous Belarusian scientist S. Yu. Solodovnikov, "the weakest link (national innovation – clarification of the authors of the article) of the system is business sector, and significant efforts should be directed precisely to its development because the business sector is a "filler" for the created innovation infrastructure, and also forms the market of innovations" [3, p. 175].

In scientific and educational literature traditionally highlights the issues concerning the external environment of business operation [4, p. 7; 5, p. 21-23]. Unfortunately, the parameters of the external environment are traditionally considered as a kind of objective reality, with which business should be passively considered and to which, alas, it can only fatally adapt.

At the same time, the study of the current stage of technical and technological progress, in the most developed countries of the world characterized as the "fourth industrial revolution" (the development strategy of Industry 4.0), shows that now these countries are fiercely competing with each other not so much in the markets of goods and services as in the sphere of purposeful creation of extremely favorable conditions for the innovative reproduction of production capital. In our opinion, this is the main economic function of the state in the modern market economic system.

A matrix of pair correlation coefficients was constructed to identify factors that directly affect the dynamics of the growth rate of production of machines, vehicles and equipment, as

well as to eliminate the prerequisites of multicollinearity or strong interdependence between exogenous variables of the model"(see "table 2 - pair correlation coefficient Matrix.").

Analysis of the coefficients of pair linear correlation allows us to establish that the greatest impact on the development of the engineering industry is the growth rate of investment in fixed assets, % (X1) – rx1y = 0.891; the growth rate of the initial cost of fixed assets, % (X3) - rx3y = 0.711; the growth rate of total costs for environmental protection, % (X6) - rx6y = 0.839; the growth rate of internal costs for research and development, % (X7) - rx7y = 0.835; the growth rate of the volume of research work performed, % (X7). x8) - rx8y = 0.821 [6, 7].

Table 2 – Pair correlation coefficient Matrix

Indicators	(Y)	(X1)	(X2)	(X3)	(X4)	(X5)	(X6)	(X7)	(X8)	(X9)	(X10)
(Y)	1										
(X1)	**0,891**	1									
(X2)	-0,324	-0,355	1								
(X3)	**0,711**	0,701	-0,392	1							
(X4)	0,44	0,305	-0,101	-0,173	1						
(X5)	**0,65**	0,648	-0,203	**0,949**	-0,277	1					
(X6)	**0,839**	**0,826**	-0,527	0,622	0,232	0,57	1				
(X7)	**0,835**	**0,723**	-0,339	0,556	0,437	0,536	**0,82**	1			
(X8)	**0,821**	**0,812**	-0,458	0,409	0,571	0,325	**0,861**	0,771	1		
(X9)	**0,583**	0,61	-0,196	**0,854**	-0,162	**0,891**	0,403	0,437	0,233	1	
(X10)	-0,141	-0,217	0,256	-0,002	-0,274	0,026	-0,1	-0,2	-0,206	-0,022	1

Source – authors' self-development

Let's carry out the graphic analysis. (see Figure 3, Figure 4, Figure 5).
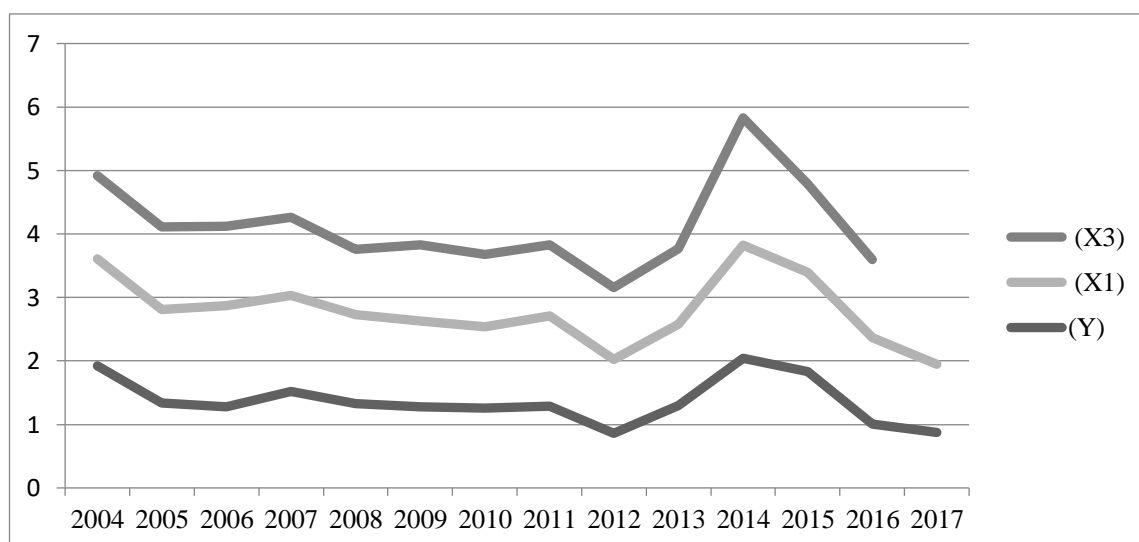

Figure 3 – Dynamics of growth rates of production of machinery, vehicles and equipment (Y) and growth rate of investments in fixed capital,% (X1), growth rate of initial cost of fixed assets,% (X3) from 2004 to 2017 years
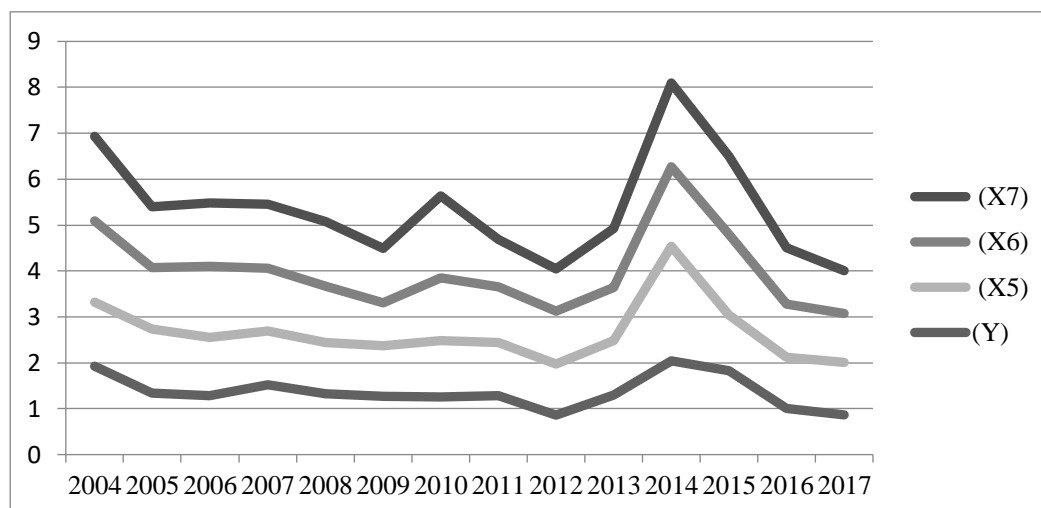
Source – authors' self-development

Figure 4 – Dynamics of growth rates of production of machinery, vehicles and growth rate
of the index of prices of producers of industrial products, % (X5), the growth rate
of total costs of environmental protection,% (X6), the growth rate of internal costs
of research and development, % (X7) from 2004 to 2017 years

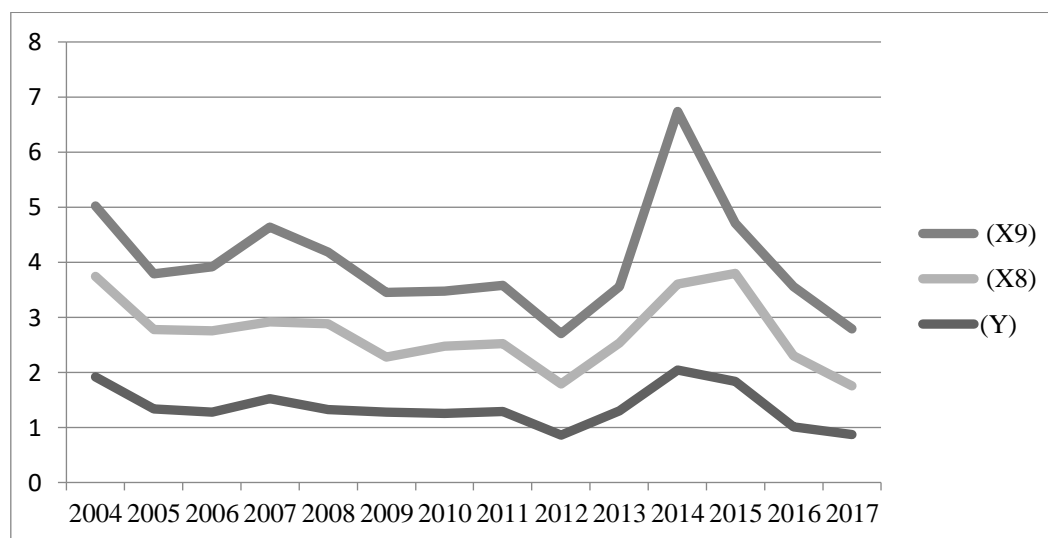Source – authors' self-development

Figure 5 – Dynamics of growth rates of production of machinery, vehicles and equipment (Y)
and the growth rate of the volume of research, % (X8), the growth rate of costs of industrial
organizations for technological innovation, % (X9)from 2004 to 2017 years

Source – authors' self-development

Conclusion: Thus, the presented analysis results demonstrate that the selected exogenous model variables (X1, X3, X5, X6, X7, X8, X9) have similar development trends as the dependent variable (Y).

Based on the results of the analysis, the author constructed the following models describing the influence of exogenous variables on the development of the engineering industry:

1) the First model has the following form:

Y = -0,971 + 1, 641X1 + Ei, i=1, ... n

In it, the growth rate of investments in fixed assets, % (X1) acts as an exogenous variable.

Conclusion: The first model is statistically significant, starting with a 20 per cent significance level, i.e. it is significant at both 10 and 5 per cent (see "Table 6 - Qualitative characteristics of the model and analysis of variancein the first model" "Table 7 - Analysis of variance in the first model", Figure 8 -Real and predicted values of the growth rate of production of machinery, vehicles and equipment (Y) in model 1, where the growth rate of investments in fixed assets is an exogenous variable, % (X1) from 2004 to 2017).

Table 6 – Qualitative characteristics of the model and analysis of variancein the first model

Multiple R	0.891
R - square	0,793106821
The normalized R-squared	0,775865723
Standard error	0.170119445
Observations	14

Source – authors' self-development

Table 7 – Analysis of variance in the first model

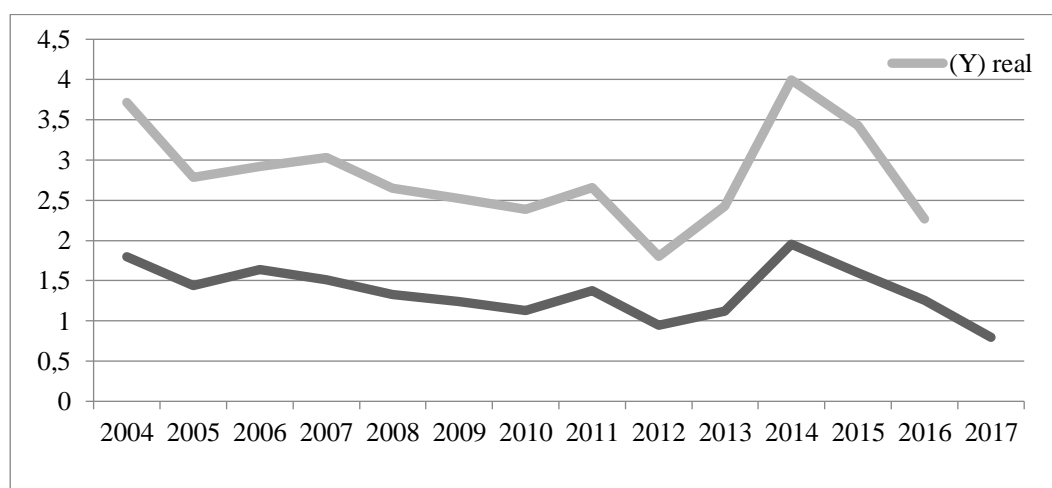|	df	SS	MS	F	F-significance			
Regression	1	1,3318	1,331	46,120	1,92685E-05			
Balance	12	0,3465	0,028					
Total	13	1,678						
	Coeffi-cients	Standard error	T-statis-tics	P-value	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Y-intersec-tion	-0,9719	0,3472	-2,79	0,016	-1,728	-0,215	-1,728	-0,215
Variable X1	1,64138	0,241	6,791	1,93E-05	1,1147	2,167	1,1147	2,1679

Source – authors' self-development

Figure 8 – Real and predicted values of the growth rate of production of machinery, vehicles and equipment (Y) in model 1, where the growth rate of investments in fixed assets is an exogenous variable, % (X1) from 2004 to 2017

Source – authors' self-development

2) Model 2 shows the dependence of the growth rate of production of machinery, vehicles and equipment on the growth rate of investment, % (X1) and the growth rate of the original cost of fixed assets, % (X3):

Y = -0,989 + 1, 42X1 + 0, 263X3 + Ei, i=1, ... n

Table 9 – Qualitative characteristics of the model and analysis of variance in the second model

Multiple R	0,898871
R - square	0,807969
The normalized R-squared	0,773055
Standard error	0,171183
Observations	14

Source – authors' self-development

Table 10 – Analysis of variance in the second model

	df	SS	MS	F	F-significance			
Regression	2	1,3562	0,67812	23,141	0,000114			
Balance	11	0,322	0,0293					
Total	13	1,6785						
	Coeffi-cients	Standard error	T-statis-tics	P-value	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Y-intersec-tion	-0,9887	0,3502	-2,82	0,016	-1,759	-0,217	-1,759	-0,217
Variable X1	1,42015	0,341	4,1599	0,0015	0,668	2,171	0,6687	2,171
Variable X3	0,263	0,2854	0,922	0,375	-0,364	0,891	-0,364	0,891

Source – authors' self-development

Conclusion: the analysis of Variance shows that the variable X3 is statistically insignificant (P-value = 0.376 > 0.05) and, therefore, it should be excluded from the model.

3) Model 3 shows the impact of the growth rate of the initial cost of fixed assets, % (X3) on the development of the engineering industry:

Y = -0.016 + 1, 096X3 + Ei, i=1, ... n

Table 11 – Qualitative characteristics of the model and analysis of variance in the third model

Multiple R	0,71124
R - square	0,505862
The normalized R-squared	0,464684
Standard error	0,262909
Observations	14

Source – authors' self-development

Table 12 – Analysis of variance in the third model

	df	SS	MS	F	F-significance			
Regression	1	0,8491	0,8491	12,2847	0,004342			
Balance	12	0,829	0,0691					
Total	13	1,678						
	Coeffi-cients	Standard error	T-statis-tics	P-value	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Y-intersec-tion	-0,015	0,4004	-0,039	0,969	-0,888	0,856	-0,888	0,856
Variable X3	1,0959	0,3126	3,504	0,0043	0,4146	1,777	0,414	1,777

Source – authors' self-development

Conclusion: the analysis of Variance indicates the statistical insignificance of the free term (P-value = 0.969 > 0.05), which suggests that it can be excluded from the model. Thus, the model has the form:

Y = 1, 096X3 + Ei, i=1, ... n

Thus, the final model is significant at 5, 10 and 20 percent significance level (see "Table 11 - Qualitative characteristics of the model and analysis of variance in the third model" "Table 12 - Analys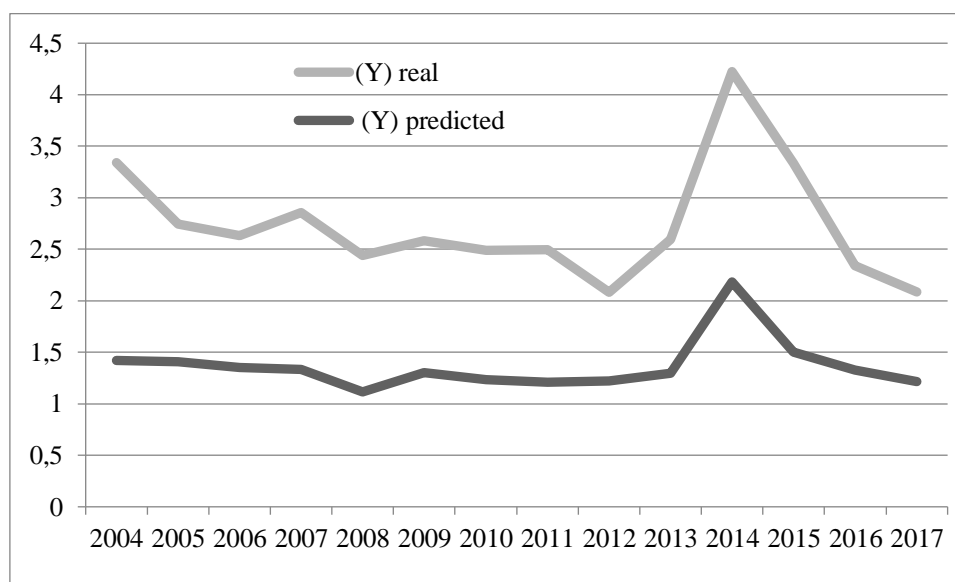is of variance in the third model", "Figure 13 - Real and predicted values of the growth rate of production of machinery, vehicles and equipment (Y) in model 3, where the growth rate of the initial cost of fixed assets is an exogenous variable, % (X3) from 2004 to 2017").

Figure 13 – Real and predicted values of the growth rate of production of machinery, vehicles and equipment (Y) in model 3, where the growth rate of the initial cost of fixed assets is an exogenous variable, % (X3) from 2004 to 2017

Source – authors' self-development

4) Model 4 describes the impact of the growth rate of the initial cost of fixed assets, % (X3) and the growth rate of internal costs for research and development, % (X7) on the development of the engineering industry:

Y = -0.329 + 0, 551X3 + 0, 727X7 + Ei, I=1,...u

Table 14 – Qualitative characteristics of the model and analysis of variance in the fourth model

Multiple R	0,886251
R - square	0,785441
The normalized R-squared	0,74643
Standard error	0,180946
Observations	0,886251

Source – authors' self-development

Table 15 – Analysis of variance in the fourth model

	df	SS	MS	F	F-significance			
Regression	1	0,8491	0,8491	12,28	0,004342			
Balance	12	0,829	0,0691					
Total	13	1,678						
	Coefficients	Standard error	T-statistics	P-value	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Y-intersection	-0,328	0,2877	-1,142	0,277	-0,96	0,3044	-0,96	0,3044
Variable X3	0,5510	0,2588	2,128	0,056	-0,018	1,120	-0,0187	1,1208
Variable X7	0,726	0,1919	3,785	0,0030	0,3041	1,1490	0,3041	1,1490

Source – authors' self-development

Conclusion: all variables x of this model are significant at 20 and 10 percent significance levels, since t0,2,12 = 1.3562 and t0,1, 12 = 1.7823, and the value of t for X3 in the model is 2,128, which is more than 1,3562 and 1,7823. Only for vzt = 1.1428 and P-value = 0.2774 > 0.05, which indicates the statistical insignificance of the free term and that it can be excluded from the model ("Table 14 - Qualitative characteristics of the model and analysis of variance in the fourth model" "Table 15 - Analysis of variance in the fourth model", "Figure 16 - Real and predicted values of the growth rate of production of machinery, vehicles and equipment (Y) in model 4, where the growth rate of the initial cost of fixed assets, % (X3) and the growth rate of internal costs for research and development, % (X7) are exogenous variables from 2004 to 2017"). Therefore, the resulting model has the form:

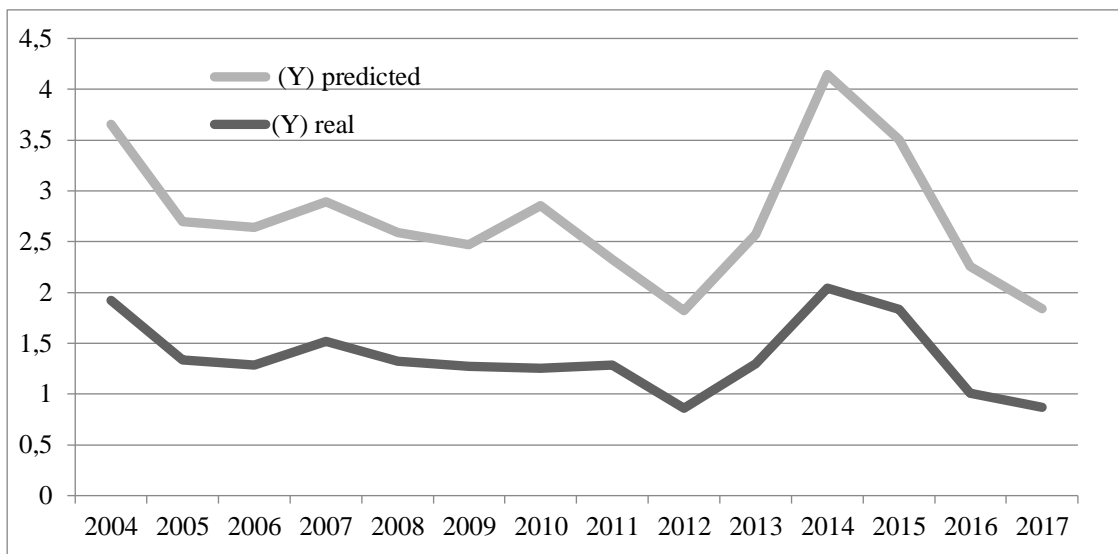**Y = 0, 551X3 + 0, 727X7 + Ei, I=1,...u**

Figure 16 – Real and predicted values of the growth rate of production of machinery, vehicles and equipment (Y) in model 4, where the growth rate of the initial cost of fixed assets, % (X3) and the growth rate of internal costs for research and development, % (X7) are exogenous variables from 2004 to 2017

Source – authors' self-development

The author made similar calculations and analysis for other exogenous variables selected using the correlation matrix.

Thus, the regression analysis allowed the author to select the following models that describe in detail the dynamics of the machinery industry, depending on the factors, which directly influence it.

Based on the statistical significance of exogenous variables, the author has compiled and proposed the following systems of equations for different levels of significance: 20%, 10%, 5%, accordingly.

System of equations significant at 20, 10 and 5 percent level:

$$Y = \begin{cases} Y_1 = -0{,}971 + 1{,}641X1 + ei, \ i=1,\dots n \\ Y_2 = 1{,}096X3 + Ei, \ i=1,\dots n \\ Y_3 = 1{,}124X6 + Ei, \ i=1,\dots n \\ Y_4 = 0{,}954X7 + Ei, \ i=1,\dots n \\ Y_5 = -0{,}841 + 0{,}457X7 + 1{,}11X1 + Ei, \ i=1,\dots n \\ Y_6 = 0{,}944X8 + Ei, \ i=1,\dots n \\ Y_7 = 0{,}694X3 + 0.732X8 + Ei, \ i=1,\dots n \end{cases}$$

System of equations significant at 20, 10 percent level:

$$
\begin{cases}
Y_1 = -0{,}971 + 1{,}641X1 + Ei, \ i=1,\ldots n \\
Y_2 = 1{,}096X3 + Ei, \ i=1,\ldots n \\
Y_3 = 0{,}551X3 + 0{,}727X7 + Ei, \ i=1,\ldots n \\
Y_4 = -0{,}503 + 0{,}694X3 + 0{,}732X8 + Ei, \ i=1,\ldots n \\
Y = Y_5 = 1{,}124X6 + Ei, \ i=1,\ldots n \\
Y_6 = 0{,}954X7 + Ei, \ i=1,\ldots n \\
Y_7 = -0{,}841 + 0{,}457X7 + 1{,}11X1 + Ei, \ i=1,\ldots n \\
Y_8 = 0{,}944X8 + Ei, \ i=1,\ldots n \\
Y_9 = 0{,}503X8 + 0{,}568X7 + Ei, \ i=1,\ldots n
\end{cases}
$$

System of equations significant at 20 percent level:

$$
\begin{cases}
Y_1 = -0{,}971 + 1{,}641X1 + Ei, \ i=1,\ldots n \\
Y_2 = 1{,}096X3 + Ei, \ i=1,\ldots n \\
Y_3 = 0{,}551X3 + 0{,}727X7 + Ei, \ i=1,\ldots n \\
Y_4 = -0{,}503 + 0{,}694X3 + 0{,}732X8 + Ei, \ i=1,\ldots n \\
Y_5 = 1{,}124X6 + Ei, \ i=1,\ldots n \\
Y = Y_6 = 0{,}865X6 + 0{,}477X3 + Ei, \ i=1,\ldots n \\
Y_7 = 0{,}954X7 + Ei, \ i=1,\ldots n \\
Y_8 = -0{,}841 + 0{,}457X7 + 1{,}11X1 + Ei, \ i=1,\ldots n \\
Y_9 = 0{,}944X8 + Ei, \ i=1,\ldots n \\
Y_{10} = 0{,}503X8 + 0{,}568X7 + Ei, \ i=1,\ldots n
\end{cases}
$$

Conclusion. 1. This system of equations clearly shows the extent to which each of the exogenous variables selected by the author on the basis of PEST-analysis, graphical analysis and correlation matrix has an impact on the development of machine-building complex of the Republic of Belarus. The system of econometric equations developed by the author demonstrates high quality characteristics, since all models have a high coefficient of determination ($R^2 >= 0{,}7$) and a high level of significance. All models are statistically significant at 5, 10 and 20 per cent, respectively, indicating that the probability that the models are unreliable is only 0.05, 0.1 and 0.2.

2. Thus, the analysis allows us to conclude that the state should not only take into account macroeconomic factors, but also should purposefully influence them for the purpose of innovative development of the industrial sector of the economy, including the machine-building complex.

3. Thus, the results of the study can be used to assess and develop forecasts for the development of the machine - building industry of the Republic of Belarus in the short and medium term.

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МОДЕЛИРОВАНИЕ РАЗВИТИЯ МАШИНОСТРОИТЕЛЬНОГО КОМПЛЕКСА РЕСПУБЛИКИ БЕЛАРУСЬ

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Машиностроительный комплекс Республики Беларусь играет особую роль в промышленности страны. Данная статья посвящена построению прогнозных моделей роста машиностроительного комплекса Республики Беларусь на основе факторов, непосредственно оказывающих на его влияние. При написании статьи авторы использовали такие инструменты, как PEST-анализ, корреляционный анализ, графический анализ и моделирование.

Ключевые слова: машиностроительный комплекс, моделирование, темп роста, корреляционная матрица, PEST-анализ, графический анализ.

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