

Labor Productivity Forecasting

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Abstract — The economic and mathematical forecasting methods used in economics allow for determination of quantitative relationships between complex socio-economic, technological and other processes with less time and money. In modern conditions, almost any indicator can be planned using the economic mathematical method. The use of these methods eliminates subjectivism in planning and increases the scientific level of plan's validity. However, the use of these methods requires an exact mathematical description of an economic problem and expert evaluation of the data obtained. The description of the algorithm made it possible to determine the growth of labor productivity and justify growth achievement through the dynamics of selected factors.

Keywords — *economics, labor productivity, well construction, economic, mathematical methods, multi-factor model, forecasting*

I. INTRODUCTION

The growth of labor productivity in Russia is one of the key tasks of the May presidential decree of 2018. To achieve a 5% increase in labor productivity, the national project "Labor Productivity and Employment Support" was developed. According to the targets of the national project, labor productivity should grow by 1.4% in 2019, by 2% in 2020, by 3.1% in 2021, by 3.6% in 2022, by 4.1% in 2023 and by 5 % I 2024.

Thus, in order to make effective management decisions and ensure implementation of national labor productivity growth projects, it is necessary to forecast production efficiency indicators.

Economic forecasting is a design stage of the long-term planning process which serves to develop a scientifically based hypothesis for development of the economic system. In terms of theory and practice, the most effective models are multifactor dynamic forecast models. These models allow for obtaining final results of high quality and justification of their achievement through a combination of material factors. Multifactorial forecasting of labor productivity in drilling (as well as other technical and economic indicators) will make it possible to identify the reserves for growth and identify ways for using these reserves when developing a production plan [1-4].

II. RESULTS AND DISCUSSION

This paper describes a method for constructing a multifactor dynamic model for production forecasting in drilling for the Volga region oil and gas association. Let us describe the method [6, 7].

Let us assume that on the basis of economic, logical and regression analysis, n factors influencing labor productivity in drilling for a particular oil and gas production association consisting of m drilling enterprises were selected. Information on these factors is provided for each drilling enterprise for N years.

Let us set number N' (N' < N) and construct a set of linear regression models from 1 to N'; from 2 to N' + 1, ..., from N' - N' + 1 to N year:

$$Y_{j \div j+N'-1} = a_0^{jN'} + a_1^{jN'} x_1 + \dots + a_n^{jN'} x_n$$

(j=1, 2, ..., N-N'+1), (1)

where $a_i^{jN'}$ indicates that the corresponding coefficients were found from statistical data from j to j + N' - 1 years.

Then the economic statistical model of labor productivity for the k-th year will be presented in a linear form.

$$Y_k = a_0^k + a_1^k x_1 + \dots + a_n^k x_n, \quad (2)$$

where the values of coefficients a_i^k are calculated as the arithmetic mean values of the corresponding coefficients $a_i^{jN'}$ of the equations of set (1) whose interval $j \div j+N'-1$ includes the k-th year.

The eligibility of the method for constructing annual models of labor productivity is based on the following provision.

If the set of values $\{Z_i'\}$ and $\{Z_i''\}$ are approximate solutions of linear equation $Y = \sum b_i Z_i$ and give errors δ_1 and δ_2 , the set of values

$$\{Z_i'''\} \text{ (where } Z_i''' = \frac{Z_i' + Z_i''}{2})$$

Is also an approximate solution of this equation with error $\delta_3 = \frac{\delta_1 + \delta_2}{2}$. The similar conclusion is true for any number of sets.

Let use this position for a set of regression equations (1). The equations of this set allow us to obtain theoretical (calculated) values of labor productivity for a given year of the retrospective period. For the fourth (from the beginning of the reference) year the calculated values of Y can be obtained from the four set of equations (1) with coefficients

$$a_i^{1N'}, a_i^{2(N'+1)}, a_i^{3(N'+2)}, a_i^{4(N'+3)},$$

Then equation (2) with coefficients

$$a_i^4 = \frac{a_i^{1N'} + a_i^{2(N'+1)} + a_i^{3(N'+2)} + a_i^{4(N'+3)}}{4}$$

gives an approximate value of Y for the fourth year and can be considered as a model.

Applying the theory of time series processing, we can predict the future value of a_i^k , i.e. we can form a multifactorial dynamic forecasting model.

Let us the forecasting algorithm to calculate the possible drilling output per one average employee (m/person) for an enterprise for a five-year period. The calculation is carried out in the following order: selection of factors for inclusion in the model, construction of regression equations, formation of a multifactor forecast model.

The following factors were considered for inclusion in the model:

A. an increase in the technical level of production:

1. a capital-labor ratio, thousand rubles / person
2. power supply of labor, kW / person;
3. proportion of active fixed assets, %.

B. Improvement of management, organization of production and labor:

4. proportion of productive drilling time, %.
5. average qualification.
6. average salary, rubles.
7. staff turnover, %.

B. Changes in the volume and structure of production.

8. annual penetration rate, m.

9. proportion of exploration drilling, %.

G. Natural factors:

10. average well depth, m

11. mechanical drilling speed, m / h.

Г. Отраслевые (природные) факторы:

10. Средняя глубина скважин, м.

11. Механическая скорость бурения, м/ч.

III. EXPERIMENT

Careful analysis of the factors allows for identification of the following four indicators included in the final forecasting model:

- capital-labor ratio – X_1 ;
- productive drilling time – X_2 ;
- mechanical drilling speed – X_3 ;
- time – X_4 .

The use of the time factor makes it possible to reduce autocorrelation in the time series and improve accuracy of the calculated values, since it takes into account long-term changes that are not associated with the changes caused by the factors included in the model [5].

The information on selected factors is analyzed for fifteen years from 2003 to 2017 (2018 was taken as a control year) for three drilling enterprises of the association.

The dynamics of changes in these factors for the whole association is presented in Table 1.

TABLE I. DYNAMICS OF CHANGES IN DRILLING FACTORS FOR 2003 – 2017

Year	Labor productivity, m/person	Capital productivity, thousand rubles/person	Use of productive time, %	Mechanical speed, m/h
2003	50.0	4574	61.7	15.44
2004	52.0	4596	61.7	15.51
2005	56.0	4580	61.2	15.75
2006	46.0	4602	55.4	15.77
2007	56.0	4613	58.6	17.28
2008	61.0	4627	63.5	17.89
2009	61.5	4794	67.8	17.25
2010	62.5	4802	67.6	16.87
2011	64.8	4820	66.4	16.69
2012	66.8	4833	71.1	16.37
2013	66.2	4972	70.5	15.96
2014	74.1	5131	73.5	15.91
2015	76.5	5279	75.6	16.10
2016	85.6	5380	76.0	16.52
2017	92.5	5392	79.3	16.62

Using the described method, the regression equations of production were constructed for five-year periods shifted by one year ($Y_{2003-2007}$, $Y_{2008-2012}$, $Y_{2013-2017}$), and then a set of annual generation equations was formed (Table 2).

TABLE II. DYNAMICS OF THE COEFFICIENTS OF PRODUCTION (M/PERSON) AND ITS CALCULATION VALUES FOR 2003 – 2017

Year	Equation coefficients						ΔY	$\bar{\varepsilon}$, %
	a_0	a_1	a_2	a_3	a_4	\bar{Y}		
2003	-21.2	1.10	0.72	3.00	2.50	48.35	1.65	3.3
2004	-23.8	1.12	0.74	2.95	2.45	48.13	3.87	7.4
2005	-25.1	1.15	0.74	2.90	2.50	51.03	4.97	8.9
2006	-25.5	1.17	0.74	2.80	2.40	48.57	-2.57	6.6
2007	-27.3	1.23	0.75	2.76	2.50	56.78	-0.78	1.4
2008	-30.6	1.27	0.74	2.73	2.50	60.89	0.11	0.2
2009	-32.5	1.43	0.74	2.40	2.48	61.35	0.15	0.2
2010	-37.1	4.52	0.75	2.34	2.40	61.07	1.13	1.8
2011	-40.9	4.64	0.77	2.37	2.42	51.42	3.48	5.4
2012	-44.7	4.67	0.78	2.45	2.36	63.87	2.93	4.4
2013	-48.5	1.70	0.82	2.50	2.31	66.14	0.06	0.1
2014	-51.5	1.76	0.85	2.50	2.29	74.35	-0.26	0.3
2015	-54.5	1.78	0.87	2.52	2.33	79.70	-3.20	4.2
2016	-55.0	1.79	0.88	2.53	2.37	86.25	-0.65	0.7
2017	-57.0	1.81	0.90	2.52	2.40	92.24	0.26	0.3

As can be seen from Table 2, the mathematical equations with a fairly high degree of accuracy describe the real process.

For example, the average deviation of the actual output values from the calculated ones was + 0.73 m/h, and the average approximation error was 2.95%.

Then, using the method of exponential smoothing, regularities for regression equation coefficient changes were identified and the following multifactor dynamic model of labor productivity forecast was constructed:

$$Y_{t+1} = (-57.5 - 3.2l) + (1.88 + 0.054)X_1 + (0.92 + 0.012l + 0.003l^2)X_2 + (2.55 + 0.04l + 0.006l^2)X_3 + (2.355 - 0.0092)X_4. \quad (3)$$

By substituting corresponding values in formula (3), we can obtain a set of mathematical models characterizing the relationship between production and factors selected for the future (Table 3).

TABLE III. DYNAMICS OF CHANGES OF THE RELATIONSHIP BETWEEN PRODUCTION (M/PERSON) AND THE FACTORS IN DRILLING

Year	<i>l</i>	Model equation
2018	1	$Y = -60.7 + 1.934X_1 + 0.935X_2 + 2.596X_3 + 2.346X_4$
2019	2	$Y = -63.9 + 1.988X_1 + 0.956X_2 + 2.654X_3 + 2.337X_4$
2020	3	$Y = -67.1 + 2.042X_1 + 0.983X_2 + 2.720X_3 + 2.327X_4$
2021	4	$Y = -70.3 + 2.096X_1 + 1.016X_2 + 2.806X_3 + 2.318X_4$
2022	5	$Y = -73.5 + 2.150X_1 + 1.055X_2 + 2.900X_3 + 2.309X_4$
2023	6	$Y = -76.7 + 2.240X_1 + 1.100X_2 + 3.000X_3 + 2.300X_4$

To determine the specific values of production by year in the set of mathematical models (see table 3), it is necessary to insert the appropriate values of factors X_1 . Capital-labor forecasting models X_1 and production time use models X_2 determined using the exponential smoothing method are as follows:

$$X_1^* = 14.8 - 0.25l + 0.27l^2; \quad (4)$$

$$X_2^* = 79.2 + 1.8l. \quad (5)$$

For mechanical speed, it was possible to find an average of the approximate function \bar{X}_3 .

Therefore, when forecasting it, the dynamics of changes in this indicator for five years was taken into account.

As a result of additional calculations, projected values of the production rate and the group of factors influencing it from 2018 to 2023 were determined (Table 4).

TABLE IV. DYNAMICS OF LABOR PRODUCTIVITY FORECASTING AND DETERMINATION OF ITS FACTORS IN DRILLING FOR 2018 – 2023

Year	X_1	X_2	X_3	X_4	H_T	Forecasting interval	
						min	max
2018	14.83	81.0	6.70	16	98.7	95.0	102.3
2019	15.46	82.8	6.80	17	103.8	95.5	111.1
2020	16.45	84.6	6.85	18	110.2	103.3	117.1
2021	18.00	86.4	6.90	19	118.6	110.7	126.5
2022	20.13	88.2	6.95	20	129.2	120.4	138.0
2023	22.73	90.0	7.00	21	141.7	132.5	151.0

Comparison of the calculated production rate for 2018 (98.7 m/person with an actual production rate in the region (99 m) confirms the practical use of the forecasting model.

The results of the above calculations suggest that the annual drilling output per worker will increase over the five-year period by approximately 40–42%. However, this increase in labor productivity is possible only if there is a corresponding increase in material factors. It should be noted that the forecasting production interval is large. This is due to a relatively short analyzed period – 15 years. In addition, it should be noted that the specificity of drilling is such that a longer period would cause incompatibility of dynamic data (bringing in new wells), i.e. there would be a heterogeneous population, especially for the last years (observations). This fact will not contribute to the improvement of the model quality. Therefore, for the practical use of the developed forecasting model, it is necessary to take the most probable (average) values of the calculated indicators.

To determine the influence of selected factors on the level of labor productivity in the forecasting period, it is necessary to find the patterns of behavior of elasticity β - coefficients of these factors. It is necessary to smooth the time series of the coefficients shifted by one year and take the element of the natural series of numbers n [8-10] as a smoothing argument.

The analysis of elasticity coefficients and β – coefficients showed that the main source of productivity growth in drilling for the current five-year period is an increase in the capital-labor ratio. The trend lines characterizing the regularity of the behavior of these coefficients are increasing parabola branches

At the same time, there is a decrease in the influence of the specific weight of productive time and mechanical speed on the level of production in drilling, although the first factor will still play a decisive role.

These results prove an assumption that further significant improvement in drilling performance can be achieved through technical re-equipment of the industry using new equipment and technologies.

IV. CONCLUSION

1. The most effective methods for forecasting labor productivity in drilling are multifactor dynamic forecast models.

2. The method described in the paper helps use these models for oil and gas producing associations and take into account the influence of the natural factor on the production rate of each association.

3. The description of the algorithm on the example of the association of oil and gas enterprises allowed for determination of the growth of labor productivity and justification of its achievement through the dynamics of selected factors.

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