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CREACIÓN DE LA FUNCIÓN DE PRODUCCIÓN DE PRC CORPORATION EN UNA ECONOMÍA INESTABLE

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Abstract

The article considers the issues of construction and analysis of the production function (PF) as a development model of the China National Petroleum Corporation (CNRC), which objectively reflects its performance under unstable economy. This circumstance directly affects both the relatively short period of the retrospection (from 2011 to 2018, N = 8 values of the studied indicators) and the nature of the initial data themselves. Before obtaining the PF, the data characteristics are calculated - a component analysis of the variables and the degree of correspondence of their elements according to their normal distribution law (NDL) according to the chi-squared test with the classification of normal and “quasinormal” distribution according to the prof. Iadov V.A. The 2016 indicator of 52.6 billion yuan according to the Grubbs criterion was withdrawn from further consideration within X = “Profit”. The remaining PF for constructing the model were aggregates by N=7. The results of the component analysis make it possible to construct the PF as a multiplicative multiple regression equation with subsequent potentiation and obtaining the PF according to the least squares method. Further, the indicators of economic growth of CNPC Corporation are considered due to the mechanical expansion of manufacturing (M) and due to the innovative element (E) of its development.

Keywords: production function, multiple regression, Cobb-Douglas function, autocorrelation residuals, forecasting, private resource efficiency.

Resumen

El artículo considera los temas de construcción y análisis de la función de producción (PF) como un modelo de desarrollo de la Corporación Nacional de Petróleo de China (CNRC), que refleja objetivamente su desempeño en una economía inestable. Esta circunstancia afecta directamente tanto el período relativamente corto de la retrospección (de 2011 a 2018, N = 8 valores de los indicadores estudiados) como la naturaleza de los datos iniciales en sí. Antes de obtener el FP, se calculan las características de los datos: un análisis de componentes de las variables y el grado de correspondencia de sus elementos de acuerdo con su ley de distribución normal (NDL) de acuerdo con la prueba de chi-cuadrado con la clasificación de normal y "cuasinormal" distribución según el prof. Iadov V.A. El indicador de 2016 de 52.600 millones de yuanes según el criterio de Grubbs se retiró de mayor consideración dentro de X = "Beneficio". Los PF restantes para construir el modelo fueron agregados por N = 7. Los resultados del análisis de componentes hacen posible construir la FP como una ecuación de regresión múltiple multiplicativa con potenciación posterior y obtener la FP de acuerdo con el método de mínimos cuadrados. Además, los indicadores de crecimiento económico de CNPC Corporation se consideran debido a la expansión mecánica de la fabricación (M) y al elemento innovador (E) de su desarrollo.

Palabras clave: función de producción, regresión múltiple, función de Cobb-Douglas, residuos de autocorrelación, pronóstico, eficiencia de recursos privados.

Introduction.

While preparing data to create the production function of the China National Petroleum Corporation (CNRC) under unstable economy, using X = "Profit", bln. yuan, K = "Volume of fixed assets", bln. yuan, and L = "Number of employees", people [1], issues related to data analysis were examined for the possibility of constructing PF of the form (1) as a multiplicative multiple regression equation of the form (2), which can be obtained after logarithmization in the form of a multiple linear regression equation (3) [2].

$$X = f\,(K, L). \quad (1)$$

Function (1) in the required multiplicative form according to [2] will be as follows:

$$X = A \cdot K^{\alpha 1} \cdot L^{\alpha 2}\,, \quad (2)$$

where A is the coefficient of neutral technical progress; α_1 and α_2 are the elasticity factors for funds and labor.

We shall logarithm the function (2) and obtain the linear multiple regression equation with respect to its unknown variables entering into equation (3) in the first power:

$$\ln X = \ln A + \alpha_1 \ln K + \alpha_2 \ln L, \quad (3)$$

which is solved by standard means. The necessary initial data are presented in Table 1, at $N = 7$ (without data for 2016) [5]:

Having the expressions (1) - (3) and the initial data for obtaining the PF model in Table 1, we proceed to the construction of the model and the subsequent analysis.

Table 1. – The initial data for modeling by equation (1), $N = 7$

i	Years	Net profit, X, bln. yuan	Fixed assets net value, K, bln. yuan	Number of workers, L, (roughly) thousand people
1	2	3	4	5
1	2011	12.4	555.3	1290
2	2012	13.1	619.7	1350
3	2013	13.9	725.4	1380
4	2014	14.1	766.6	1300
5	2015	12.4	832.8	1300
6	2017	26.8	876.6	1400
7	2018	17.6	894.4	1360

2. METHODS. The issues of preparing the source data for constructing the multiple regression model (3) and (2) under turbulent economy are inextricably linked with a preliminary analysis of the selected source data given in Table 1, in order to conduct component analysis and test hypotheses about the normal distribution of the elements of the studied statistical aggregates X, K, and L. While preparing data to create the CNPC production function, it was found that the elements of these aggregates can be considered distributed according to the normal distribution law (NDL) or approximately distributed as “quasinormal” with estimation of error, as suggested by the authors, in percentage according to V.A. Iadov scale [3, p. 62]. Due to the fact that the profit in 2016 exceeded the usual profit for the study period by several times, the Grubbs criterion [4] was applied to the statistical population X, as a result of which the information for 2016 was derived from the Table 1, as a result of which the powers of the studied variables decreased from $N = 8$ to $N = 7$.

As initial data, representatives of that company, which, due to the nature of its production due to known existing macroeconomic and political factors [5], was, along with other parties, a specific example of an unstable, or in a different way, turbulent economy were used [6, p. 90], [7, p. 84]. Therefore, the selection of this company as a subject of research in a turbulent economy is relevant. Therefore, the objectives of the research are as follows:

1. Based on the results of the previous studies on the preparation of data to create the production function of the CNRC corporation, to accept the statistical properties of the variables X, K, and L for the initial construction of function (3) as a linear multiple regression equation using a special computer system with the subsequent PF working equation in the form of (2).

2. To estimate the magnitude of autocorrelation excess. In the case of absence, the function *X* depends only on the arguments (regressors) *K* and *L*, but if there is a noticeable autocorrelation, the values of the same function depend not only on the regressors, but also on itself, and the construction of forecasts becomes fundamentally incorrect, i.e. impossible.

3. To analyze the obtained PF, reduced to the Cobb-Douglas form to assess the types of development of the company due to either extensive or intensive growth.

To achieve the first stated goal, we must obtain the PF. After solving the multiple regression equation (3) and the corresponding potentiation of the PF, its construction acquired the form (4) [2, p.16], that is, the form of function (2):

$$X = a \cdot K^{\alpha 1} \cdot L^{\alpha 2} = 16{,}8 \cdot 10^{-14} \cdot K^{0{,}5804} \cdot L^{4{,}8901}, \qquad (4)$$

where a = ln *A* – the constant term from equation (3).

Validation of the obtained equation (4) consists in comparing the average values of the variables:

$$X_{av} \equiv 16{,}8 \cdot 10^{-14} \cdot K_{av}^{\;0{,}5804} \cdot L_{av}^{\;4{,}8901}.$$

$$15{,}757.143 \equiv 16{,}8 \cdot 10^{-14} \cdot 753{,}028^{\;0.5804} \cdot 1340^{\;4.8901} = 15{,}376.788 \text{ (bln. yuan)}$$

As we can see, the right and left sides of equation (4) differ by only 2.5%, which is insignificant, that is, the coefficients of equation (4) are correct.

The reliability parameters as a result of using the author's computer program (author - A.M. Shikhalev) of the resulting final PF equation (4) are as follows: the reliability of the obtained Fisher equation is only 72.6% instead of at least 90% expected by us; the significance of the regression coefficients in the same Student t-test is also insufficient: 68.6% and 84.6% - less than 90%, respectively. Apparently, the factor of precisely the quasinormal distribution of the elements *K* and *L* as statistical aggregates with a sufficiently small volume ($N = 7$) affected it, although at first there were 8 of them before applying the Grubb's test.

The multiple correlation coefficient $R = 0.8054$ is quite high, and the coefficient of determination $R^2 = 0.6487$ indicates that the independent model variables cover at least 64.87% ≈ 65% of all cause-effect relationships of the equation in the form (4), and characterizes far from sufficient coverage of the existing exogenous factors *K* and *L* on the resulting (endogenous) indicator *X*.

Finding additional factors is a promising task. The natural logarithm of the approximation error *EPS* = 1.354%. Therefore, the total relative approximation error *EPS* = $e^{1.354}$ = 3.88%. According to prof. V.A. Iadov's scale [3] the reliability character refers to "increased": approximation error from 0% to 3%; reliability character is "ordinary" (3 - 10%), "approximate" (10 - 20)%, etc.

Therefore, the nature of the approximation accuracy of the obtained preliminary linear model (3) and the general working model (4) (2) can be estimated as "normal" (the approximation error does not exceed 10%). For further analysis of possible forecasting, we need to prove the noticeable absence of autocorrelation residues of the obtained formula (4).

The estimation of the values of possible autocorrelation (a/c) excess is carried out as follows. Calculations by means of a computer program for autocorrelation E give the following results: $r_{\alpha}^{calculation}$ = - 0.371; $d_{\alpha}^{calculation}$ = 2.590, which, in comparison with the tabular data, allows us to conclude that for the number of variables $v = 3$ (variables X, K, L) and for $N = 7$ [8. - P. 133]:

$$r_{\alpha}^{calculation} = -0.371 > r_{\alpha}^{table} = -0.674 \qquad (5)$$

with a significance level of α = 0.05. Therefore, the phenomenon of autocorrelation in statistical residuals according to strict inequality (5) is clearly present. On the other hand, to clarify this conclusion, it is recommended to use the Darbin-Watson test at $\alpha = 0.05$. For this, two tabular values are selected from the corresponding table: $d_1 = 0.82$ and $d_2 = 1.75$, based on which the following values are calculated: $(4 - d_2) = (4 - 1.75) = 2.25$ and $(4 - d_1) = (4 - 0.82) = 3.18$ [8, p. 132]. We will present the obtained indicators for clarity in Fig. 2 following the example of a visual representation of the mechanism for testing the hypothesis about the presence of autocorrelation residues [9, p. 276]. Figure 2 shows that the obtained value of the Darbin-Watson test equal to 1.43 (indicated by an arrow in Fig. 2) is closer to the autocorrelation-free zone.

positive a/c	zone undefined	a/c free	zone undefined	negative a/c
0	0.82 1 ↑ 1.43	1.75 2	2.25 3 3.05	3.18 4

Fig. 2. Graphical interpretation of the assessment of the presence of autocorrelation excess

Although the calculated value of the autocorrelation coefficient r = -0.371 according to the table of Appendix 7 [8, p. 133] with a sample size of $N = 7$ and a significance level of α = 0.05 gives a tabular value (- 0.671). That is, the following strict inequality of the calculated and tabulated values of the autocorrelation coefficient - 0.371> - 0.671 indicates the presence of a negative value of the autocorrelation coefficient. But according to the Darbin-Watson test, the phenomenon of autocorrelation is still in the zone of uncertainty, although closer to the zone of its absence, which requires additional consideration when discussing the results of forecasting.

After evaluating the autocorrelation of the obtained PF model (4), it is necessary to carry out its additional analysis. For this purpose, to assess the growth factors of the enterprise under study, the cited method [2] recommends distinguishing between extensive growth factors (by increasing the cost of resources M) and intensive factors (by increasing the utilization efficiency of resources E). Moreover, production efficiency is estimated as the ratio of achieved results to costs [2]. Preliminary calculations are made based on columns 3, 4, and 5 according to the source data table (see Table 1):

1) income of the studied enterprise increased by $X^* = (X_{2018} / X_{2011})$ = (17.6 billion yuan / 12.4 billion yuan) = 1.419 times;

2) fixed assets increased by $K^* = (K_{2018} / K_{2011})$ = (894.4 billion yuan / 555.7 billion yuan) = 1.610 times;

3) the number of workers employed in production increased by $L^* = (L_{2018} / L_{2011})$ = (1360 thousand people / 1290 thousand people) = 1.054 times.

Further analysis requires an economic interpretation of the regression parameters a, α_1, α_2 of the equations in the additive and multiplicative form (3) and (4), respectively. The parameter "a" is interpreted as a parameter of neutral technical progress: for fixed α_1 and α_2, the income at the point (K, L) increases along with the value "α". Here α_1 acts as the elasticity of output for fixed assets, and α_2 - the elasticity of output for labor.

If, following from the working model (4) $\alpha_1 + \alpha_2 > 1$; $\alpha_1 + \alpha_2 = 0.5804 + 4.899 = 5.4705 > 1$. Then the resulting indicator of "income X" grows faster than the average regressors K and L, and the resulting model (4) is typical for a growing economy. For further analysis, we bring the PF of the form (4) to the form of the Cobb-Douglas PF [2]:

$$X = a \cdot K^{\alpha} \cdot L^{(1-\alpha)}, \tag{6}$$

where $\alpha = \alpha_1 / (\alpha_1 + \alpha_2) = 0.5804 / (0.5804 + 4.8901) = 0.1061$; then $(1 - \alpha) = (1 - 0.1061) = 0.8939$, and the expression of the standard multiplicative function (4) in the form of the Cobb-Douglas function on the basis of the general expression (6) takes the form:

$$X = a \cdot K^{0.5804} \cdot L^{4.8901} \tag{7}$$

Next, it is necessary to determine the *private resource efficiency* for capital productivity (E_C) and labor productivity (E_L) according to formulas (8) and (9):

$$E_C = X^* / K^* = 1.419 / 1.610 = 0.881; \tag{8}$$

$$E_L = X^* / L^* = 1.419 / 1.054 = 1.346, \tag{9}$$

Based on formulas (8) and (9), a generalized efficiency indicator E as a geometric mean has the following form:

$$E = E_K^{\alpha} \cdot E_L^{(1-\alpha)} = 0.881^{0.1061} \cdot 1.3463^{0.8939} = 1.287 \approx 1.29 \text{ (times).} \tag{10}$$

Then the average scale of production over time can also be defined as the geometric mean, based on the growth rate of resources:

$$M = K^{*\alpha} \cdot L^{*(1-\alpha)} = 1.610^{0.1061} \cdot 1.054^{0.8939} = 1.102 \approx 1.10 \text{ (times).} \tag{11}$$

Consequently, the total income growth of the investigated production from 2011 to 2018 increased by 1.10 times according to (11), and occurred due to an increase in the scale of production, and by 1.29 times according to (10) due to an increase in production efficiency.

Moreover, the ratio of scale growth and efficiency growth can be expressed subject to expressions (10) and (11) as their ratio: $S = E / M = 1.29 / 1.10 = 1.17$ times. In other words, for 2011 - 2018, in the overall growth, the share of production efficiency is noticeably higher than the share of growth in its scale, which is positive in general.

Further, after analyzing the Cobb-Douglas function of the form (6) based on formula (4), we can start to build forecasts. To implement the development forecasts of the studied company, we choose short-term forecasts (up to 1 year) for 2019, taking into account the fact that probabilistic forecasts using the "random-walk method" [10] in an unstable economy are more productive than purely statistical ones, and they are generated in the form of "mathematical expectation (ME)" ± rmsd or MO ± σ:

- by profit X: 19.389 ± 3.436 or [15.953; 22.825]; (12)

- by volume of fixed assets K: 954.461 ± 13.447 or [941.014; 967.908]; (13)

- by personnel L: 1379.624 ± 29.636 or [1344.988; 1409.260]. (14)

Since the forecast for X was obtained directly from the source data of the Table 1 (column 3), forecasts using the obtained model (4) will be of more interest, when the independent variables will take the values presented in expressions (13) and (14). The combination of their extreme values will lead to four obvious variations of the computational experiment:

1) K = 941.014 bln. yuan, L = 1344.988 people: X = 17,820.929 mln. yuan;

2) K = 941.014 bln. yuan, L = 1409.260 people: X = 22,390.611 mln. yuan; (15)

3) K = 967.908 bln. yuan, L = 1344.988 people: X = 18,114.855 mln. yuan;

4) K = 967.908 bln. yuan, L = 1409.260 people: X = 22,759.820 mln. yuan.

Among all the options we created (15), the fourth option - ($K_{av} + \sigma_K$) и ($L_{av} + \sigma_L$) provides the maximum profit of 22,759.820 million, which is to be expected for a growing economy of a company in which profit growth occurs as a result of innovative development (E = 1.29), rather than purely mechanical expansion of production (M = 1.10) with their ratio E/M = 1.29/1.10 = 1.17 times.

Results and discussion.

To do this, we shall compare the results of direct forecasting of net profit X from expression (12): 19.389 ± 3.436 or [15.953; 22.825] billion yuan with the expected forecast interval using our developed model (4): [17,820.929: 22,759.820] mln. yuan from the obtained forecasting results for different rmsd signs given in four versions (15). The comparison shows that the new interval has narrowed, and along the lower border it is very significant: in 2019 we expect net profit not to be approximately 16.0 billion yuan, but 17.8 billion yuan (for more than about 11%), although the expectation of the upper profit margin decreased from about 22.82 billion yuan up to 22.76 billion yuan (decreased by about 0.3%).

Summary.

Therefore, we have formulated an approach not to direct forecasting of net profit from a short-term forecast with a lead-time period of one year, i.e., for 2019 in relation to the retrospection period 2011 - 2018, but using preliminary forecasts of independent factors included in the model - the size of the fixed assets K and the number of employees L, using the obtained multifactor model (3) and (4), which gives more specific results: the interval where the expected profit is located narrowed by about 11.3%.

In other words, CNPC should expect an increase in its net profit in 2019, according to (15), approximately from 17.8 to 22.7 billion yuan with reliability, taking into account the very nature of the calculated rmsd (with a probability of about 70%), which exceeds the results of 2018 (17.6 billion yuan) from 0.20 to 5.1 billion yuan, and, in turn, is a relative increase from 1.1% to 28.9%.

Conclusions.

A more accurate forecast with the implemented approach would be really difficult to expect with such a limited amount of initial data (see Table 1), however, taking into account the always valid rule, remember: "the interval forecast is approximate but reliable". Therefore, the results obtained may be useful in managing the corporation.

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