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COBB-DOUGLAS PRODUCTION FUNCTION AS A TOOL FOR ASSESSING ECONOMIC EFFICIENCY OF AN ENTERPRISE

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ВИРОБНИЧА ФУНКЦІЯ КОББА-ДУГЛАСА ЯК ІНСТРУМЕНТ ОЦІНКИ ЕКОНОМІЧНОЇ ЕФЕКТИВНОСТІ ПІДПРИЄМСТВА

The article examines the essence of the category of 'economic efficiency' as a fundamental indicator that allows a comprehensive assessment of the efficiency of resource use in achieving the highest results at the lowest cost. This indicator reflects the ability of an enterprise to combine and use its main resources - in particular, labor and capital - as efficiently as possible, which are critical factors for ensuring stable economic growth, increasing competitiveness and maintaining a strong position in the market. The problem of resource efficiency is particularly relevant for businesses operating in unstable economic conditions, which require not only an analysis of current productivity but also the development of reliable forecasts to make informed management decisions. In this regard, the study of economic efficiency is gaining practical significance, and the development of models for quantifying the impact of key production factors is becoming critical for making strategic decisions on optimising operations. The main purpose of the article is to define an approach to assessing the efficiency of an enterprise, which is based on the use of modern economic instruments and allows building a functional model of efficiency assessment. To this end, the article substantiates the feasibility of using the Cobb-Douglas production function, which is one of the most effective tools in economic theory for quantitative analysis of the impact of the main production factors on the performance of an enterprise. The Cobb-Douglas production function is of considerable methodological value, as it allows for a detailed analysis of the relationship between output and the level of labor and capital costs. This function helps to determine how changes in labor and capital inputs affect the overall productivity of an enterprise, as well as to assess the large-scale return on the use of these resources, which makes it possible to identify the optimal combination of factors to achieve maximum economic benefit.

У статті досліджено сутність категорії «економічна ефективність» як фундаментального показника, що дозволяє всебічно оцінити ефективність використання ресурсів у досягненні найвищих результатів за мінімальних затрат. Цей показник відображає здатність підприємства максимально

ефективно поєднувати й використовувати свої основні ресурси — зокрема, трудові та капітальні — що є критичними факторами для забезпечення стабільного економічного зростання, підвищення конкурентоспроможності та підтримки надійної позиції на ринку. Проблема ефективності ресурсів особливо актуальна для підприємств, що діють у нестабільних економічних умовах, які потребують не лише аналізу поточної продуктивності, а й розробки надійних прогнозів для ухвалення виважених управлінських рішень. У зв'язку з цим дослідження економічної ефективності набуває практичної значущості, а розробка моделей для кількісного оцінювання впливу основних виробничих факторів стає критично важливою для прийняття стратегічних рішень щодо оптимізації діяльності. Основною метою роботи є визначення підходу до оцінки ефективності діяльності підприємства, який базується на використанні сучасних економічних інструментів і дозволяє побудувати функціональну модель оцінки ефективності. Для цього обґрунтовано доцільність застосування виробничої функції Кобба-Дугласа, яка є одним із найефективніших інструментів в економічній теорії для кількісного аналізу впливу основних факторів виробництва на результативність діяльності підприємства. Виробнича функція Кобба-Дугласа має значну методологічну цінність, адже дозволяє детально проаналізувати залежність між обсягом випуску продукції та рівнем затрат на трудові й капітальні ресурси. Завдяки такій функції можна визначити, яким чином зміна обсягів праці та капіталу позначається на загальній продуктивності підприємства, а також оцінити масштабну віддачу від використання цих ресурсів, що дає змогу виявити оптимальну комбінацію факторів для досягнення максимальної економічної вигоди.

Keywords: effectiveness of activity, net sales revenue, modelling, production function, optimisation

Ключові слова: ефективність діяльності, чистий дохід від реалізації, моделювання, виробнича функція, оптимізація

Statement of the problem in general and its connection with important scientific or practical tasks. One of the pressing problems of modern enterprise management is the need to assess and improve the economic efficiency of production processes. In the context of dynamic changes in the market environment arising in the face of uncertainty, enterprises are obliged not only to use available resources efficiently, but also to ensure sustainable growth of production indicators at optimal costs. This issue is of particular importance for management decision-making and strategic planning, as the level of efficiency directly affects the competitiveness and financial stability of the enterprise. The Cobb-Douglas production function, which is used to model the impact of labor and capital factors on performance, provides an opportunity to assess the contribution of each of these factors to total output. This allows not only to determine the level of resource efficiency, but also to forecast future results, taking into account changes in production factors.

Analysis of recent research and publications. Modern research confirms the importance of assessing the economic efficiency of enterprises. Yaroslavskyi A. O. and Batrakova T. I. emphasise the importance of rational use of resources and the need for enterprises to adapt to market challenges. Chyzhevskaya M. B. and other scholars substantiate the use of production functions to analyse the impact of labor and capital factors, and Shumska S. S. proves the effectiveness of this approach for resource optimisation.

Formulation of the objectives of the article (statement of the task). The aim of this article is to build an economic-mathematical model based on the Cobb-Douglas production function to assess the efficiency of enterprise and analyse the impact of the main factors of production – labor and capital - on net income. The use of the model will allow to identify trends and efficiency of resource use, as well as to formulate recommendations for optimising management decisions in terms of the enterprise's resource policy.

Summary of the main research material. In modern economic science, one of the key areas of research is the optimisation of production processes and

improving the efficiency of enterprises, especially in conditions of uncertainty. Economic processes are now often influenced by external, difficult to predict factors, such as wars, political conflicts, global crises and climate change, which can significantly change the economic environment.

Evaluating economic efficiency is an important aspect of any business, as it helps to determine how efficiently the available resources are used to achieve the highest results at the lowest cost. In a market environment, every business seeks not only to maximise profits but also to ensure the stability and competitiveness of its operations. This is only possible if resources such as labor, capital and materials are used optimally, with minimal losses and maximum results.

In general, modern scholars interpret the concept of economic efficiency as an indicator that reflects the degree to which available resources are used to achieve the highest results at the lowest cost. Economic efficiency assesses how optimally an enterprise organises the process of production, use of capital, labor and other resources to maximise profits or other performance indicators [1].

Economic efficiency implies not only cost containment, but also the correct allocation and use of resources, which allows a company to achieve high productivity and profitability. Efficiency can be assessed through various indicators, such as labor productivity, capital efficiency or material intensity of products, but a comprehensive approach to assessing production processes requires taking into account the relationship between all production factors [2].

One of the most effective and widely used valuation methods is the use of production functions, in particular the Cobb-Douglas function. This mathematical model allows to determine the contribution of individual factors of production, such as labor and capital, to total output and to estimate the elasticity of production by these factors. The Cobb-Douglas function takes into account the interaction of factors, which allows enterprises to determine the optimal ratio of labor and capital to maximise productivity [3].

The Cobb-Douglas production function is as follows:

$$Y = A * L^{\alpha} * K^{\beta} \quad (1)$$

Y – volume of product output;

A

– an efficiency parameter that shows the level of technological development;

L – amount of labor involved;

K – amount of capital;

α, β – elasticities of output by labor and capital.

The analysis uses linear regression in logarithmic form, which allows for simplified calculation and obtaining the coefficients directly from the regression. Logarithmisation reduces the influence of scale, transforming the model into a convenient linear form, which simplifies the estimation of function parameters using regression analysis [4].

$$\ln Y = \ln A + \beta * \ln K + \alpha * \ln L \quad (2)$$

The Cobb-Douglas function is based on the assumption that output growth is driven by the interaction of capital and labor, and that these factors make a relatively constant contribution to output growth. Typically, $\alpha + \beta = 1$, which means constant returns to scale. If $\alpha + \beta > 1$, there are increasing returns to scale, and if $\alpha + \beta < 1$, there are decreasing returns to scale [4].

In order to estimate the net income from sales of «Zvyagelkhib», we will build a production function based on the indicators of the labor remuneration fund and fixed capital. To model the dynamics of net sales income, we use data from the financial statements of the enterprise, which contain information on the above indicators. The data presented in the table allows us to analyse the efficiency of using the payroll fund and fixed assets to generate net income and to build a production function of the enterprise based on these factors.

Table 1. Indicators of the activity of PJSC «Zvyagelkhlil» for modelling net sales revenue

Period	Y net revenue from sales of products	K fixed assets	L labor costs
2015	59668	6877	12145
2016	59560	9991	14342
2017	67214	13847	17424,8
2018	81334	15697,2	23460,1
2019	91417,4	18116	29452,3
2020	86728,6	21247,1	31304,8
2021	90955	21562,3	30000
2022	102450,9	25678	30182,5
2023	105756,7	31508,3	32684,6

Source: compiled based on [5].

For the correct analysis and construction of a production function, it is important to use homogeneous data that takes into account changes in the value of money over time. Since economic indicators such as net sales revenue, fixed assets and labor costs are measured in monetary units, their values are significantly affected by inflation, which changes the real purchasing power of money in each period. Therefore, to ensure the accuracy of the model, it is necessary to bring the data to a single price level, i.e. to the prices of 2023.

Table 2. Indicators of «Zvyagelkhlil» in 2023 prices

Period	Inflation index	Y Net revenue from sales of products adjusted to 2023 prices	K Property, plant and equipment restated to 2023 prices	Labor costs adjusted to 2023 prices
2015		133949,1	15438,2	27264,4
2016	1,124	118956,1	19954,5	28644,5
2017	1,137	118067,7	24323,6	30608,3
2018	1,098	130119,2	25112,6	37531,8
2019	1,041	140490,6	27840,7	47118,2
2020	1,05	126937,9	32652,6	45774,8
2021	1,1	121021,6	31559,1	39917
2022	1,266	107675,9	34166,3	31721,8
2023	1,051	105756,7	31508,3	32684,6

Source: compiled based on [5,6].

At the next stage of the study, it is necessary to logarithmise the indicators of net income from sales, fixed capital and wage fund to build the Cobb-Douglas production function in a linear form. On the basis of the processed logarithmic data, the calculated values are obtained, which reflect the estimated net income of the enterprise for the relevant periods. These data are presented in Table 3 and allow us to assess the compliance of the built model with real data and check the accuracy of the calculated elasticities.

Table 3. Results of modelling the net income of «Zvyagelkhlil»

Period	ln(Y)	ln(K)	ln(L)	Y calculated
2015	11,81	9,64	10,21	119441,13
2016	11,69	9,90	10,26	112230,62
2017	11,68	10,10	10,33	109087,85
2018	11,78	10,13	10,53	121319,90
2019	11,85	10,23	10,76	129115,69
2020	11,75	10,39	10,73	125070,81
2021	11,70	10,36	10,59	121578,36
2022	11,59	10,44	10,36	113713,95
2023	11,57	10,36	10,39	109239,88

Source: compiled based on [5,6].

Thus, based on the calculations and regression analysis, the Cobb-Douglas production function for «Zvyagelkhlil»:

$$\ln Y = \ln 10,283 - 0,401 * \ln K + 0,526 * \ln L; \quad (3)$$

$$Y = e^{10,283} * K^{-0,401} * L^{0,526}; \quad (4)$$

$$Y = 29237,1 * K^{-0,401} * L^{0,526}. \quad (5)$$

$a = 0,526$ which means that with a 1% increase in labor costs, the increase in net sales revenue will be 0.52%;

$\beta = -0,401$ means that a 1% increase in the value of fixed assets will result in a 0.4% decrease in net sales revenue.

The observation that output decreases with increasing capital indicates that capital may be overcapitalised or inefficiently used. This suggests that the current level of capital may be higher than the optimal level, leading to a decrease in

efficiency. It is important to analyse whether capital is being used to its maximum potential or whether there is room for optimisation.

A positive labor ratio indicates that as labor resources increase, output increases. A value of the coefficient that is less than one indicates an increasing but decreasing return on labor. This means that the involvement of additional labor improves productivity, but the efficiency of this labor has its limitations.

The sum of the coefficients for capital and labor that is less than one indicates declining returns to scale. This means that doubling the amount of inputs does not lead to doubling the output, which indicates that there are limitations in the production process and the need to improve technology.

The Cobb-Douglas production function shows that the company uses labor much more efficiently than capital. This indicates the potential for optimising the management of capital resources, as there is an opportunity to increase productivity through more efficient use of capital.

SUMMARY OUTPUT								
<i>Regression Statistics</i>								
Multiple R	0,9745							
R Square	0,9496							
Adjusted R Square	0,9328							
Standard Error	0,0246							
Observations	9							
<i>ANOVA</i>								
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	2	0,0685	0,0343	56,5337	0,0001			
Residual	6	0,0036	0,0006					
Total	8	0,0722						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95,0%</i>	<i>Upper 95,0%</i>
Intercept	10,283181	0,462954	22,212083	0,000001	9,150373	11,415990	9,150373	11,415990
X Variable 1	-0,401102	0,041902	-9,572420	0,000074	-0,503632	-0,298572	-0,503632	-0,298572
X Variable 2	0,526495	0,055283	9,523550	0,000076	0,391221	0,661768	0,391221	0,661768

Fig. 1. Results of modelling net sales revenue for «Zvyagelkhliv»

Source: compiled based on [5,6].

Analysis of the quality of the model built by the Cobb-Douglas function includes an assessment of statistical indicators that reflect the adequacy and accuracy of the model. These indicators allow us to draw several important conclusions.

The coefficient of multiple determination - the value shows a high correlation between the model factors and output, which indicates a strong relationship between the independent variables - the cost of fixed assets and the payroll fund and the dependent variable - net sales revenue. The coefficient of determination shows that 94.96% of the variation in the dependent variable is explained by the independent variables of the model. This indicates a high explanatory power of the model, which is a positive characteristic. The adjusted coefficient of determination takes into account the number of observations and shows that 93.28% of the variation in the dependent variable is explained by the model variables, taking into account the limited sample size. This also indicates strong model adequacy given the small number of observations. The significance indicator indicates that the model is statistically significant at the 99.99% confidence level, as the p-value is well below the typical thresholds (0.05 or 0.01). This indicates that the independent variables of the model have a statistically significant effect on the dependent variable. The model constant is 10.283 with a high significance (p-value = 0.000001), which shows that, even without the labor and capital variables, the model predicts the baseline level of output. The value of the coefficient for the cost of capital variable is -0.401 with a p-value of 0.000074, indicating its high significance. The negative sign means that with an increase in this factor, output decreases. The coefficient for the labor fund is 0.526 with a p-value of 0.000076, which indicates its significance. The positive sign indicates a positive effect of the capital variable on output. The low value of the standard error of the model indicates that the predicted values are close to the actual data, which indicates high accuracy of the model.

The model based on the Cobb-Douglas function shows high correlation, determination and statistical significance of the coefficients. This means that the model is adequate for analysing production processes and can be used to forecast output when labor and capital factors change.

Changes in the costs of capital and labor can have a significant impact on the performance of an enterprise, so it is important to be able to predict their future

values in order to make accurate forecasts. In this regard, in order to adequately forecast the dynamics of net income, it is advisable to build trend models for each of the inputs, which will allow you to determine their long-term trends and help you take these changes into account in your forecasts.

Trend models for capital and labor costs allow you to estimate future changes in these indicators, taking into account their historical trends. Trend analysis is based on the use of mathematical models, such as linear, exponential or polynomial functions, which can be approximated based on available data. The use of such models allows us to forecast future capital and labor costs based on available historical information, which is critical for further net income forecasts.

The results of the trend models for forecasting fixed capital expenditures are shown in Table 4. The modelling was carried out using three different types of functions: linear, exponential and logarithmic, with the determination of the coefficient of determination for each model.

Table 4. Trend models for the factor ‘Cost of fixed assets’

Type of model	Equation	Coefficient of determination
Linear	$y = 2776 * x + 4400$	0,975
Exponential	$y = 7810e^{0,155x}$	0,965
Logarithmic	$y = 3953 + 10072 \ln x$	0,885

Source: compiled based on [5,6].

Since the linear model has the highest coefficient of determination, it is the most appropriate for forecasting fixed capital expenditures based on historical data. This model provides the highest accuracy and allows you to make reliable forecasts of future costs, which is important for planning the company's net income (Fig. 2).

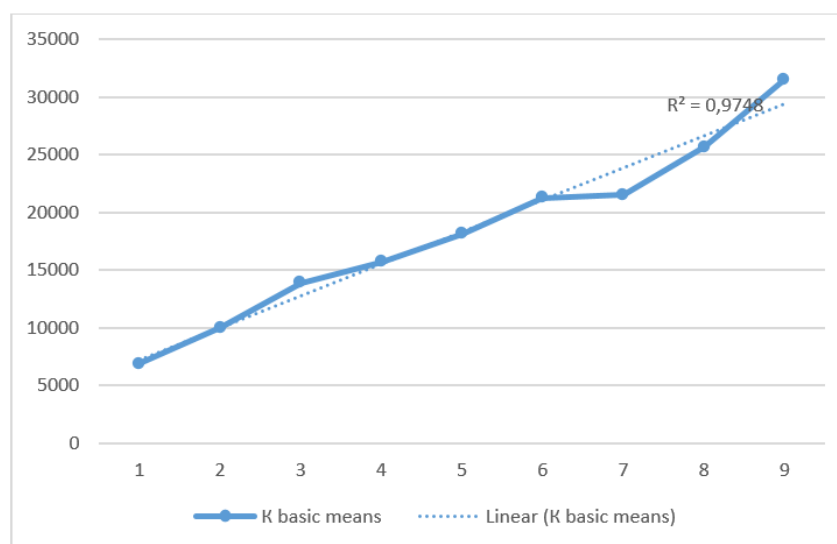


Fig. 2. Linear trend in the dynamics of fixed assets of «Zvyagelkhlil»

Source: compiled based on [5,6].

Similarly, trend models were built to forecast labor costs (Table 4). For each of the models, determination coefficients were also calculated to assess the accuracy of each function in explaining the dynamics of labor costs.

Table 5. Trend models for the labor remuneration fund

Type of model	Equation	Coefficient of determination
Linear	$y = 2711 * x + 10999$	0,869
Exponential	$y = 13678e^{0,111x}$	0,788
Logarithmic	$y = 9534 + 10560 \ln x$	0,91

Source: compiled based on [5,6].

In this case, the logarithmic model with the coefficient of determination $R^2 = 0,91$ is the most accurate for forecasting labor costs. Its high accuracy indicates that changes in labor remuneration tend to slow down over time, which may be typical for enterprises that have reached a certain level of development and optimisation of personnel costs (Fig. 3). Therefore, the logarithmic model will be chosen for further use in the analysis and forecasting of labor costs, as it provides the highest accuracy in predicting future values of this indicator.

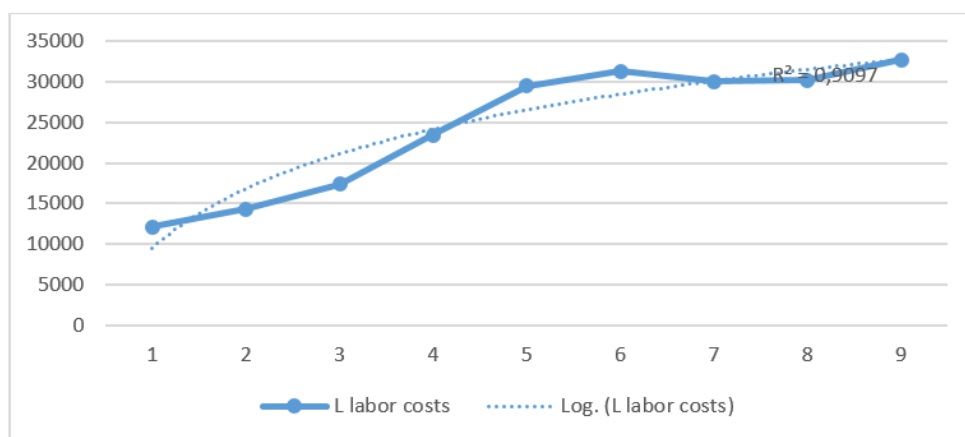


Fig.3. Logarithmic trend in the dynamics of the payroll fund

Source: compiled based on [5,6].

Thus, based on the built trend models for labor costs and fixed assets, the values of these factors for the coming years were determined. The forecasts for the payroll fund for 2024 and 2025 are 33,849.30 and 34,855.77, respectively, and for fixed assets - 32,160 and 34,855.77.

Applying the model, we obtained forecasts for the net income of the enterprise for 2024 and 2025. According to the results of the calculations presented in Table 6, the company's net income from sales of products in 2024 is projected at UAH 110,362.38 thousand, and in 2025 - UAH 108,417.28 thousand.

Table 6. Forecast values of net sales revenue of «Zvyagelkhib» according to the Cobb-Douglas function

Period	K Property, plant and equipment are adjusted to 2023 prices	L Labor costs are adjusted to 2023 prices	Y Net sales revenue adjusted to 2023 prices
2015	15438,22	27264,39	119441,13
2016	19954,50	28644,53	112230,62
2017	24323,56	30608,30	109087,85
2018	25112,58	37531,77	121319,90
2019	27840,74	47118,16	129115,69
2020	32652,62	45774,82	125070,81
2021	31559,07	39916,98	121578,36
2022	34166,27	31721,81	113713,95
2023	31508,30	32684,60	109239,88
2024	32160	33849,30	110362,38
2025	34936	34855,77	108417,28

Source: compiled based on [5,6].

The projected values of net income from sales of «Zvyagelkhlub» products are shown in Figure 4.

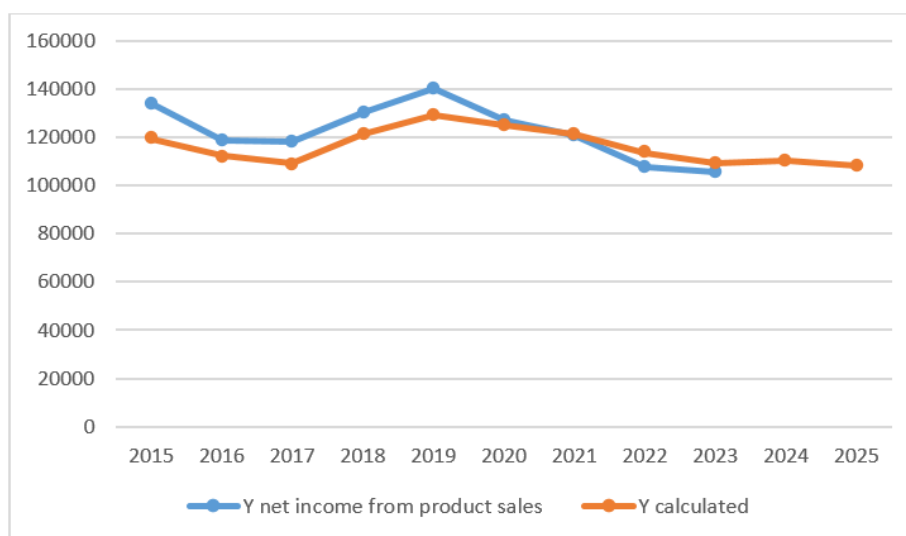


Fig.4. Actual and forecasted values of net income from sales of products of «Zvyagelkhlub»

Source: compiled based on [5,6].

Conclusions and prospects for further research in this area.

Based on the results of the analysis of the Cobb-Douglas production function, a number of important conclusions can be drawn about the efficiency of the enterprise, as well as directions for improving its functioning.

1. The need to optimise capital.

The observation that output decreases with increasing capital indicates that there may be excess capital or its inefficient use. This indicates that the current level of capital may exceed the optimal level, which leads to a decrease in the efficiency of its use. The company should pay attention to analysing whether the capital is being used to the maximum extent possible or whether there are opportunities for its optimisation. If this hypothesis is confirmed, it is worth considering reducing capital investments or improving their management in order to achieve higher production results while maintaining the current level of investment.

2. Labor efficiency.

A positive labor coefficient indicates that an increase in labor resources contributes to the growth of output. However, a value of the coefficient that is less than one indicates an increasing but decreasing return on labor. This means that although hiring additional labor improves productivity, the efficiency of this labor has its limitations. In this regard, the enterprise should focus on improving the skills of employees, improving organisational processes, and introducing innovative technologies to ensure greater productivity from additional labor.

3. Declining returns to scale.

A sum of capital and labor ratios that is less than one indicates declining returns to scale. This means that a doubling of inputs does not lead to a doubling of output. This phenomenon is a signal that there are constraints in the production process that limit the efficiency of resource use. This indicates the need to improve technologies and processes at the enterprise, which will allow achieving better results when expanding production.

4. Prospects for optimising capital resources.

The analysis of the Cobb-Douglas production function shows that the company uses labor much more efficiently than capital. This indicates that there is potential for optimising the management of capital resources, as there is an opportunity to increase the enterprise's productivity through more efficient use of capital. The enterprise should focus on improving its investment strategy, introducing more modern equipment and technologies, and allocating capital investments more efficiently.

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