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MODERN ANALYTICAL APPROACHES TO MEASURING THE ECONOMIC EFFICIENCY OF MANUFACTURING ENTERPRISES

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СУЧАСНІ АНАЛІТИЧНІ ПІДХОДИ ДО ВИМІРЮВАННЯ ЕКОНОМІЧНОЇ ЕФЕКТИВНОСТІ ВИРОБНИЧИХ ПІДПРИЄМСТВ

The article presents a comprehensive study of modern analytical approaches to measuring the economic efficiency of manufacturing enterprises in the context of the transformational development of the national economy. It is substantiated that economic efficiency acts as one of the key criteria for assessing the performance of enterprises and reflects the level of rational use of labour, material, and financial resources. The concept of "economic efficiency" is defined as an integral indicator combining economic, organizational, and technological dimensions of enterprise functioning, which characterizes its ability to achieve maximum results with minimal costs. It is emphasized that under conditions of uncertainty and growing risks, the efficient utilization of resource potential becomes a decisive factor for ensuring the stability and competitiveness of manufacturing systems.

The paper generalizes methodological approaches to quantitative measurement of efficiency considering internal and external factors, which enables the formation of a comprehensive diagnostic system of enterprise performance. The methodological framework of the study is based on the application of economic and mathematical modelling and the Cobb–Douglas production function as a key analytical tool. This approach provides an opportunity to quantitatively evaluate the influence of major production factors—labour and capital—on the output volume, to identify the marginal productivity of resources, and to determine the elasticity of production with respect to input factors. The results make it possible to identify reserves for increasing productivity and to develop practical recommendations for optimizing the resource potential of manufacturing enterprises.

The practical significance of the research lies in the development of proposals aimed at improving the analytical evaluation system of enterprise efficiency, oriented towards enhancing production performance and achieving sustainable development. The proposed analytical tools can be applied in strategic planning, resource efficiency monitoring, optimization of management decisions,

and further academic research on economic growth and industrial modernization in Ukraine.

У статті представлено комплексне дослідження сучасних аналітичних підходів до вимірювання економічної ефективності виробничих підприємств у контексті трансформаційного розвитку національної економіки. Обґрунтовано, що економічна ефективність виступає одним із ключових критеріїв оцінювання результативності діяльності підприємств і відображає рівень раціонального використання трудових, матеріальних і фінансових ресурсів. Поняття «економічна ефективність» визначено як інтегральний показник, що поєднує економічні, організаційні та технологічні аспекти функціонування підприємства і характеризує його здатність досягати максимальних результатів за мінімальних витрат. Наголошено, що в умовах невизначеності та зростання ризиків ефективне використання ресурсного потенціалу стає вирішальним чинником забезпечення стабільності та конкурентоспроможності виробничих систем.

У роботі узагальнено методологічні підходи до кількісного вимірювання ефективності з урахуванням внутрішніх і зовнішніх факторів, що дає змогу сформувати комплексну систему діагностики результативності діяльності підприємства. Методологічну основу дослідження становить застосування економіко-математичного моделювання та виробничої функції Кобба–Дугласа як ключового аналітичного інструменту. Такий підхід забезпечує можливість кількісно оцінити вплив основних виробничих факторів — праці та капіталу — на обсяг випуску продукції, виявити граничну продуктивність ресурсів і визначити еластичність виробництва відносно факторів залучення. Отримані результати дають змогу ідентифікувати резерви підвищення продуктивності та розробити практичні рекомендації щодо оптимізації ресурсного потенціалу виробничих підприємств.

Практична значущість дослідження полягає у розробленні пропозицій, спрямованих на вдосконалення системи аналітичного оцінювання ефективності діяльності підприємств, орієнтованої на підвищення результативності виробничих процесів і досягнення сталого розвитку. Запропонований аналітичний інструментарій може бути використаний у стратегічному плануванні, моніторингу ефективності використання ресурсів, оптимізації управлінських рішень, а також у подальших наукових дослідженнях, присвячених проблематиці економічного зростання та модернізації промислового сектору України.

Ключові слова: *економічна ефективність; виробниче підприємство; аналітичні підходи; ресурсний потенціал; виробнича функція Кобба–Дугласа; економіко-математичне моделювання; факторний аналіз; стратегічна результативність.*

Keywords: *economic efficiency; manufacturing enterprise; analytical approaches; resource potential; Cobb–Douglas production function; economic and mathematical modelling; factor analysis; strategic performance.*

Problem statement. Currently, manufacturing enterprises operating under conditions of economic uncertainty continuously face the challenge of maintaining effective control and improving the efficiency of their production processes in order to ensure sustainable development and strengthen their market competitiveness. In an environment characterized by dynamic market fluctuations, resource constraints, and increasing technological complexity, enterprises must focus on the rational use of available resources to achieve stable growth in production indicators. The issue of economic efficiency thus becomes a cornerstone for evaluating enterprise performance and for determining the ability of a firm to transform input resources into measurable economic results.

Given these circumstances, the assessment of economic efficiency plays a crucial role in managerial decision-making, strategic planning, and long-term

development forecasting. The application of advanced analytical and modelling tools becomes essential for identifying inefficiencies, evaluating productivity reserves, and optimizing resource allocation. In this context, the Cobb–Douglas production function provides a valuable methodological framework for analysing the relationship between labour and capital as the key production factors, as well as for measuring the contribution of each factor to the overall production outcome. This analytical approach not only enables the assessment of efficiency levels but also supports the identification of future trends in enterprise development under the influence of changing production and market conditions.

Analysis of recent research and publications. The concept of economic efficiency has been widely explored in numerous modern scientific studies. Theoretical and methodological foundations revealing the essence of this concept and outlining ways to enhance efficiency within enterprises have been thoroughly analysed in the works of Yaroslavskyi A. O., Batrakova T. I., Rohach S. M., Biletska K. Yu.**,** and others. Cherkashyna T. S., Chyzhevska M. B., Shumska **S. S.**, and other researchers have substantiated the application of production functions to analyse the impact of labour and capital factors and to optimize the use of enterprise resources.

Task Definition. The primary task of this study is to develop a scientifically grounded economic and mathematical model based on the Cobb–Douglas production function, which enables a comprehensive assessment of the economic efficiency of a manufacturing enterprise. The model aims to examine the interrelation between the main production factors—labour and capital—and the net revenue from product sales. This analytical approach makes it possible to evaluate the effectiveness of resource utilization, to determine the elasticity of production with respect to input factors, and to identify efficiency trends that may guide further managerial and strategic decision-making.

Research results. The activity of any enterprise under the conditions of modern economic development and prevailing uncertainty requires continuous analysis and monitoring of its economic efficiency. The economic processes of each business entity are often influenced by external factors such as war, global

crises, and geopolitical instability, which may negatively affect the enterprise's performance indicators as they directly impact the overall state of the economic environment. The indicator of economic efficiency plays a crucial role for any business, since it allows for assessing the effectiveness of resource utilization aimed at profit maximization, ensuring stable economic development, and maintaining enterprise competitiveness.

The interpretation of the concept of economic efficiency in the current context of dynamic economic development under uncertainty necessitates a clear definition of its essence and content (Table 1).

Table 1. The Essence of the Concept of "Economic Efficiency"

Author	Essence of the Concept of "Economic Efficiency"
Yaroslavskyi A. O.	Obtaining the maximum possible benefits from the resources available for use.
Batrakova T. I.	An indicator reflecting the aspiration toward the final result — not the result itself, but the correctness and accuracy of movement toward it.
Rohach S. M.	Economic efficiency is a complex category that reflects the degree of utilization of an enterprises or resource's potential and is expressed through the ratio of results to costs, taking into account the industry-specific context (for example, ecological aspects in agriculture).
Biletska K. Yu.	Economic efficiency demonstrates the final useful effect obtained from the use of means of production and living labour, as well as from their combined contribution.

Source: systematized based on [1; 2; 3; 4].

Economic efficiency of enterprise activity is defined as the optimal utilization of the available resources within an enterprise to ensure the achievement of maximum performance results.

In this study, in order to determine the optimal use of enterprise resources, a model is constructed based on the Cobb–Douglas production function. The Cobb–Douglas production function is a macroeconomic model that describes the functional dependence of production output on the inputs of capital and labour. It was developed in 1928 by American scholars Paul Douglas (economist) and

Charles Cobb (mathematician) for analysing the manufacturing industry of the United States.

The methodological foundation of this model is based on the assumptions of the physical productivity of production assets (or capital, according to Western terminology) and the participation of only two main production factors — capital and labour — under conditions of perfect competition [7].

The Cobb–Douglas production function is expressed as follows:

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

where:

Y – total output (volume of production);

A – efficiency parameter indicating the level of technological development;

L – amount of labour employed;

K – amount of capital utilized;

α, β – output elasticities with respect to labour and capital, respectively.

For the purpose of further analysis, the logarithmic form of the linear regression model is applied. This transformation significantly simplifies the calculation process and allows for the direct determination of elasticity coefficients.

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

Based on the sum of the elasticity coefficients α and β, the following conclusions can be drawn:

$\alpha + \beta = 1$ – constant returns to scale;

$\alpha + \beta > 1$ – an expansion of production yields a more than proportional increase in output;

$\alpha + \beta < 1$ – additional resources generate a less than proportional increase in output.

To apply this analytical method to the company LLC "SHILZ", the required data were collected, namely the values of net income from product sales (Y), fixed assets (K), and labour costs (L) (Table 2).

Table 2. Performance indicators of LLC "SHILZ"

Period	Net income from product sales (Y), thousand UAH	Fixed assets (K), thousand UAH	Labour costs (L), thousand UAH
2015	911 456,16	1 372 216,45	37 179,35
2016	2 350 012,93	2 258 658,56	64 114,85
2017	8 021 614,85	2 685 425,17	309 344,73
2018	11 526 364,72	2 788 297,11	646 171,79
2019	14 670 395,56	3 155 213,78	673 165,81
2020	15 188 813,26	3 185 926,28	855 970,14
2021	34 251 820,78	5 305 867,45	1 868 906,69
2022	54 939 158,10	6 172 748,45	1 429 009,06
2023	216 760 543,29	17 350 234,04	4 960 326,46
2024	244 479 860,10	35 338 760,25	5 063 632,22

Source: systematized based on [9].

To ensure the accuracy of further analysis and the construction of the production function, it is important to use data adjusted for inflation, since all indicators in the table directly depend on the value of money (Table 3).

Table 3. Inflation-adjusted performance indicators of LLC "SHILZ"

Period	Net income (Y), thousand UAH	Fixed assets (K), thousand UAH	Labour costs (L), thousand UAH	Inflation index
2015	2 291 669,89	3 450 157,30	93 479,86	
2016	5 256 785,00	5 052 432,81	143 419,63	1,124
2017	15 781 609,91	5 283 266,93	608 600,38	1,137
2018	20 652 827,40	4 996 043,45	1 157 804,28	1,098
2019	25 250 980,85	5 430 817,62	1 158 666,58	1,041
2020	24 898 373,20	5 222 552,95	1 403 155,31	1,050
2021	51 043 225,15	7 906 983,65	2 785 108,14	1,100
2022	64 669 981,78	7 266 065,66	1 682 115,14	1,266
2023	242 771 808,48	19 432 262,12	5 555 565,64	1,051
2024	244 479 860,10	35 338 760,25	5 063 632,22	1,120

Source: systematized based on [8;9].

The logarithmically transformed indicators were also calculated (Table 4).

Table 4. Logarithmically transformed performance indicators of LLC "SHILZ"

Period	ln(Y)	ln(K)	ln(L)
2015	14,64	15,05	11,45
2016	15,48	15,44	11,87
2017	16,57	15,48	13,32
2018	16,84	15,42	13,96
2019	17,04	15,51	13,96
2020	17,03	15,47	14,15
2021	17,75	15,88	14,84
2022	17,98	15,80	14,34
2023	19,31	16,78	15,53
2024	19,31	17,38	15,44

Source: created based on [8].

Based on the results of the performed calculations and regression analysis, the model constructed on the basis of the Cobb–Douglas production function can be presented as follows:

$$Ln\,Y = Ln(-4{,}590) + 0{,}696 * Ln\,K + 0{,}776 * Ln\,L; \quad (3)$$

$$Y = 0{,}0102 * L^{0.776} * K^{0.696}. \quad (4)$$

After analysing the obtained results, the following conclusions can be drawn:

$$\alpha = 0{,}776, \beta = 0{,}696, \alpha + \beta > 1 \quad (5)$$

An increase in investments in fixed assets and labour costs by 1% leads to an increase in net income from product sales by 0.696% and 0.776%, respectively. To determine the adequacy of the model, an analysis of statistical indicators was carried out (Figure 1).

Regression Statistics								
Multiple R	0,9903							
R-square	0,9808							
Adjusted R-square	0,9753							
Standart Error	0,2339							
Observations	10							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Регрессия	2	19,5234	9,7617	178,4221	0,000001			
Остаток	7	0,3830	0,0547					
Итого	9	19,9064						
	Coefficients	*Standart Error*	*t-Stat*	*P-Value*	*Lower 95%*	*Upper 95%*	*Lower 95%*	*Upper 95%*
Intercept	-4,590	1,9220	-2,3884	0,0483	-9,135205335	-0,04562	-9,135205335	-0,04562
X Variable 1	0,696	0,1715	4,0597	0,0048	0,290635013	1,101519	0,290635013	1,101519
X Variable 2	0,776	0,0901	8,6108	0,0001	0,562831509	0,988974	0,562831509	0,988974

Figure 1. Analysis of statistical indicators of the model

Based on the analysis results, it can be concluded that the model is adequate, since the coefficient of determination $R^2 = 0.98$ indicates that 98% of the variance in net income from product sales is explained by the independent variables. The F-statistic significance value of 0.000001 confirms the model's overall significance at the 99.99% confidence level. Because the p-values of the independent variables and the constant are less than 0.05, all indicators are statistically significant, which further supports the adequacy of the model.

In general, the enterprise LLC "SHILZ" effectively utilizes its resources, as $\alpha + \beta > 1$, meaning that the expansion of production yields a more than proportional increase in output. The constructed model also indicates that, at this stage, it is more reasonable to allocate a larger portion of investment to labour costs rather than to fixed assets, since $\alpha > \beta$, implying that the return on labour investment is higher than the return on investment in fixed assets. However, the coefficient for fixed assets is also positive, which suggests that the focus should not be completely shifted but rather that proportional investment would be most appropriate to maximize the overall outcome.

For further forecasting of the net income from product sales, it is necessary to predict the values of fixed assets and labour costs using trend models (Table 5, 6).

Table 5. Models for forecasting the value of fixed assets

Model type	Equation	Coefficient of determination (R^2)
Exponential	$y = 888\,970{,}21e^{0{,}30x}$	0,85
Linear	$y = 2\,644\,605{,}83x - 6\,583\,997{,}33$	0,56
Logarithmic	$y = = 8\,596\,085{,}83\ln(x) - 5\,022\,547{,}94$	0,35
Polynomial (3rd degree)	$y = 197\,133{,}50x^3 - 2\,491\,420{,}80x^2 + 9\,272\,364{,}14x - 6\,749\,849{,}80$	0,98

Source: calculated by the author

The polynomial model of the third degree demonstrates the highest value of the coefficient of determination, $R^2 = 0.98$. Therefore, it is advisable to use this model for forecasting the value of fixed assets (Figure 2).

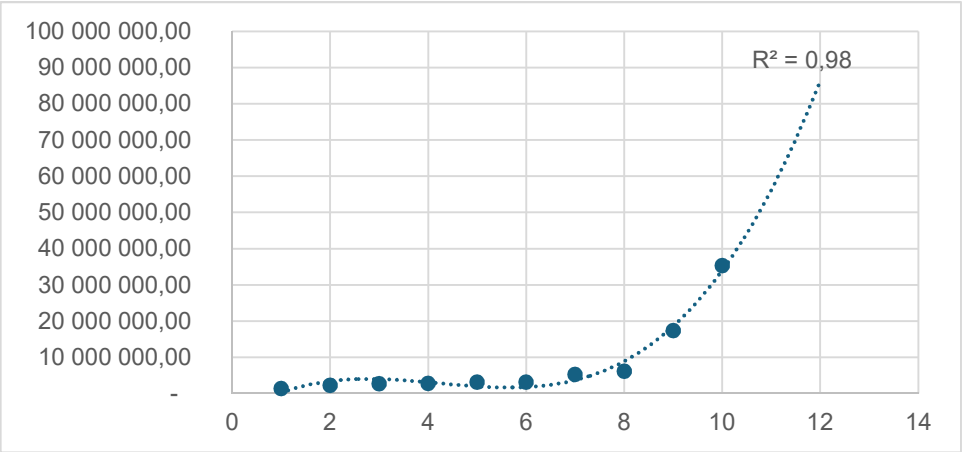

Figure 2. Forecast of the dynamics of fixed assets value

Table 6. Models for forecasting labour costs

Model type	Equation	Coefficient of determination (R^2)
Linear	y = 539 156,90x - 1 374 580,82	0,75
Logarithmic	y = 1 868 522,51ln(x) - 1 231 511,38	0,52
Polynomial (3rd degree)	24 995,14x2,18	0,87

The power model demonstrates the highest coefficient of determination, $R^2 = 0.87$. Therefore, it is advisable to use this model for forecasting labour costs (Figure 3).

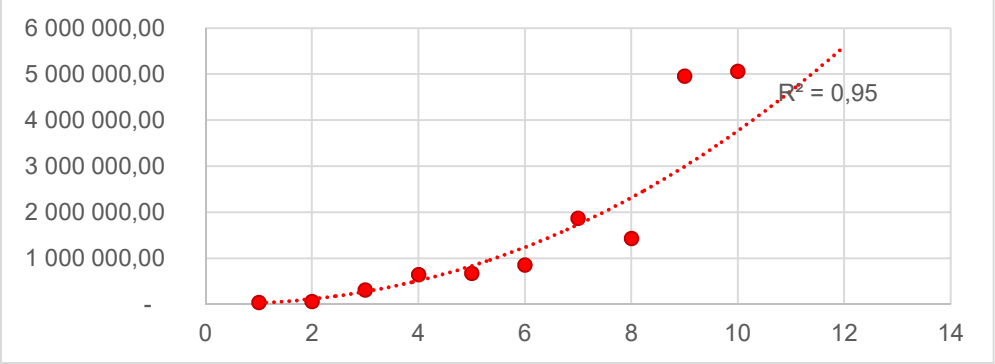

Figure 3. Forecast of the Dynamics of Labour Costs

Thus, the forecasted values of fixed assets and labour costs for 2025 amount to 56,128,027.44 UAH and 4,656,843.33 UAH, respectively. For 2026, these values are 86,435,052.68 UAH and 5,629,511.23 UAH, respectively.

Using the obtained model based on the Cobb–Douglas production function, as well as the forecasted values of fixed assets and labour costs, the future values of net income from product sales can be calculated (Table 7, Figure 4).

Table 7. Forecast of net income from product sales

Period	Y	K	L	Y – calculated value
2015	911 456,16	1 372 216,45	37 179,35	671 120,50
2016	2 350 012,93	2 258 658,56	64 114,85	1 449 039,00
2017	8 021 614,85	2 685 425,17	309 344,73	5 543 407,57
2018	11 526 364,72	2 788 297,11	646 171,79	10 078 274,73
2019	14 670 395,56	3 155 213,78	673 165,81	11 338 273,28
2020	15 188 813,26	3 185 926,28	855 970,14	13 754 351,53
2021	34 251 820,78	5 305 867,45	1 868 906,69	35 956 930,92
2022	54 939 158,10	6 172 748,45	1 429 009,06	32 439 967,39
2023	216 760 543,29	17 350 234,04	4 960 326,46	174 933 364,30
2024	244 479 860,10	35 338 760,25	5 063 632,22	291 639 077,09
2025	---	56 128 027,44	4 656 843,33	377 110 305,82
2026	---	86 435 052,68	5 629 511,23	590 067 368,40

Source: calculated by the author

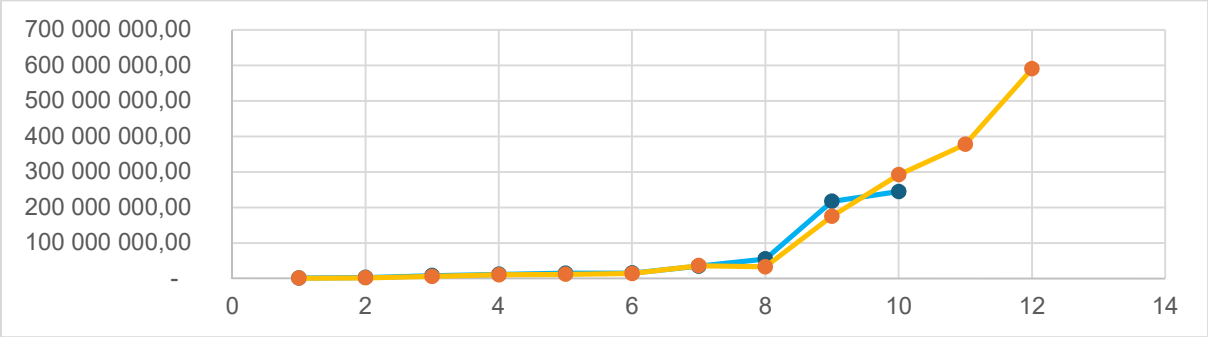

Figure 4. Forecast of the Dynamics of net income from product sales of LLC "SHILZ"

Conclusions and Discussion. Based on the conducted study of the Cobb–Douglas production function, it has been established that the enterprise demonstrates increasing returns to scale, indicating significant potential for further expansion of its production activities. The estimated elasticities show that labour costs have a stronger influence on net income compared to investments in fixed assets. This confirms the necessity to strengthen the strategic focus on the

development of human capital. The enterprise should prioritise measures aimed at improving employee qualifications, enhancing motivation systems, maintaining competitive wage levels, and creating conditions that support higher labour productivity. At the same time, investments in fixed assets should remain an important component of the long-term strategy, as they ensure technological renewal, modernisation of production facilities and sustained competitive capability.

The modelling results further highlight the importance of technological modernisation. The implementation of automated and digital solutions, the use of energy-efficient technologies, the optimisation of production processes and the adoption of modern managerial approaches will support increases in productivity and reductions in operational costs. Such technological development will strengthen the enterprise's resilience to external challenges and contribute to its long-term competitiveness.

Another key direction for development is the establishment of a system for continuous monitoring of investment efficiency. The enterprise should introduce analytical tools for assessing the impact of capital investments and labour costs on economic performance. Regular updates of forecasts based on econometric models, in particular the Cobb–Douglas model, will enable more accurate assessments of growth prospects, better-grounded strategic decisions, and timely responses to changes in the external environment.

Future research prospects include expanding the model by incorporating additional factors that influence enterprise efficiency, such as innovation activity, the level of digital transformation, energy efficiency and external economic conditions. A promising direction is the use of panel data for groups of enterprises within the industry, which would make it possible to form a more generalised view of resource efficiency, identify best practices and assess the resilience of production systems under crisis conditions. Such an approach will deepen scientific understanding of the determinants of economic efficiency and enhance the practical value of research for a wide range of manufacturing enterprises.

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