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The impact of operating leverage and financial elasticity on the budgeting of variable costs in grain production

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▸ **Abstract.** The sustainability of financial strategies in agricultural enterprises depended on accurate forecasting of production parameters and associated credit risks under volatile market conditions. This study aimed to assess the technological response of grain production to changes in resource supply and to integrate the results into liquidity forecasting and negative interest rate risk assessment. The estimated quadratic production function adequately captured the nonlinear response of wheat yield to variable inputs, confirming diminishing marginal returns. The model demonstrated satisfactory statistical performance ($R^2 = 0.606$, adjusted $R^2 = 0.409$) and was statistically significant ($F = 3.073$, $p = 0.027$). The identified technological optimum corresponded to a maximum predicted yield of 55.1 c/ha, achieved at fertiliser and seed expenditures of approximately 5.3 and 0.85 thousand UAH/ha, respectively. When value-based indicators were applied, the optimum shifted toward profit maximisation. The maximum marginal profit reached 9.32 thousand UAH/ha at slightly lower input levels, with a corresponding yield of 53.8 c/ha, while the maximum net profit equalled 5.46 thousand UAH/ha after accounting for fixed costs. The operating leverage analysis revealed pronounced nonlinearity of financial sensitivity. Extremely high DOL values (up to 9.99) occurred in underfunded production regimes, where net profit approaches zero, indicating critical operational instability, whereas a stable DOL range of 1.1-1.6 corresponded to moderate input levels. Scenario analysis of credit conditions (±20% interest rate variation) indicated asymmetric interest rate risk. The highest financial elasticity of net profit ($E \approx 0.10$) was observed in low-input, loss-making regimes, while near the technological optimum elasticity approaches zero, indicating relative financial resilience. The results confirmed that integrating production modelling with financial sensitivity indicators improved liquidity forecasting and credit planning in grain production

▸ **Keywords:** parabolic production function; resource optimisation; marginal profit; liquidity; interest rate risk; financial planning

▸ Introduction

The relevance of this study was determined by the growing need to improve cost management in grain production as a critical condition for ensuring the financial stability of agricultural enterprises under increasing market volatility. Agricultural producers operated in a highly uncertain environment characterised by seasonality of cash flows, biological constraints, climate risks, price volatility for both inputs and outputs, and limited access to financial resources. These factors significantly increased financial risks and complicated managerial decision-making in budgeting, liquidity planning, and debt servicing, especially in economies exposed to macroeconomic instability. Scientists K. Abid *et al.* (2024) demonstrated that excessive financial leverage negatively affected firm performance, particularly in emerging markets, where enterprises faced higher sensitivity to macroeconomic shocks. Similar conclusions were reached by J.D. Odhiambo *et al.* (2025), who emphasised that optimal leverage levels were essential for balancing profitability and financial resilience. A.A. Hegde *et al.* (2022) further showed that firms with higher financial flexibility demonstrated more adaptive leverage dynamics, enabling them to better withstand revenue fluctuations and financial stress. S. Byoun (2021) argued that financial flexibility played a strategic role in corporate financial decisions, allowing enterprises to mitigate

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liquidity constraints and maintain solvency during adverse economic conditions.

In the context of agricultural enterprises, these relationships became more complex due to sector-specific features. R. Bachynsky (2022) substantiated the principles of managing economic stability of agricultural enterprises, highlighting that traditional financial models often underestimated production risk, seasonality, and biological uncertainty. I. Svynous *et al.* (2021) analysed accounting and analytical aspects of cost management in agriculture and confirmed that ineffective cost control significantly amplified financial instability, especially under volatile price conditions. O. Lotysh & A. Kardash (2021), analysing global grain markets, identified strong price cyclicality and exposure to geopolitical and climatic shocks, which further complicated revenue forecasting and cost planning for grain producers. The interaction between operating leverage, production capacity, and financial distress had also been examined in empirical studies. R. Maronrong *et al.* (2022) confirmed that high operating leverage combined with financial leverage substantially increased the probability of financial distress, particularly in sectors characterised by volatile demand and cost structures. These findings were directly applicable to grain production, where high fixed costs, long production cycles, and dependence on natural conditions intensified financial vulnerability.

Ukrainian scholars had significantly contributed to the understanding of financial risk management in agribusiness. O. Tomilin *et al.* (2023) conducted a comprehensive empirical analysis of financial risk management practices in Ukrainian agricultural enterprises, identifying key vulnerabilities related to liquidity shortages, excessive short-term borrowing, and inadequate integration of production and financial planning. Their results demonstrated that most enterprises relied on fragmented budgeting practices, which limited their ability to forecast financial stress and respond proactively to adverse market changes. The authors emphasised the necessity of implementing integrated financial planning models that incorporated production risks, cost variability, and credit constraints. O. Tomilin & Ya. Oleksashenko (2025) explored agricultural insurance as a stabilisation mechanism for farm finances, providing empirical evidence that insurance instruments significantly reduced income volatility and enhance financial sustainability. Scientist's analysis showed that farms utilising insurance coverage exhibited higher liquidity ratios, lower probability of insolvency, and greater access to external financing. Importantly, the authors argued that insurance mechanisms should be embedded into broader financial management frameworks, linking risk transfer instruments with cost planning, budgeting, and capital structure decisions. This approach reinforced the need for integrated financial models that accounted for both production and financial risks in agricultural enterprises.

Despite extensive research, existing studies often treat cost management, financial leverage, and risk management as separate analytical domains. Corporate finance literature focused on industrial and service firms, where production functions exhibited relatively stable input-output relationships. In contrast, agricultural production was characterised by nonlinear responses to inputs, biological constraints, and significant exposure to exogenous shocks, which fundamentally altered the transmission mechanisms between cost structures, operating leverage, and financial performance. The interaction between nonlinear production functions, cost intensity, and financial sensitivity remained insufficiently integrated into unified budgeting and risk assessment frameworks for agriculture. The aim of this study was to develop an adaptive cost management model for grain production that optimised resource allocation, while minimising financial risks under conditions of economic instability. The objectives of the research were: 1) to analyse cost management approaches specific to grain production; 2) to adapt operating leverage and financial sensitivity indicators to agricultural conditions; 3) to develop a scenario-based budgeting framework integrating nonlinear production functions with financial risk indicators. The scientific novelty of the research lain in constructing an integrated analytical framework that combined production economics and financial risk management, thereby enhancing the financial stability and resilience of grain-producing enterprises in volatile market environments.

▸ Materials and Methods

The methodological approach to integrating operating leverage and financial elasticity into the budgeting of agricultural enterprise costs was based on combining production and financial logic of analysis. The study focused specifically on grain production, allowing for a detailed assessment of the interplay between input allocation, yield response, and financial sensitivity. The research was conducted in several consecutive stages to ensure reproducibility of results by other researchers.

Production basis of analysis

The foundation of the study was the law of diminishing returns, typical for agricultural production: the increase in yield from additional expenditures on specific resources decreases after reaching a certain level of their use. To formalise this relationship, a parabolic specification of the production function was applied:

$$Y(X_k) = \beta_0 + \beta_1 X_k + \beta_2 X_k^2, \beta_2 < 0, \quad (1)$$

where Y – yield, c/ha; X_k – expenditures on the respective resource, thousand UAH/ha; β_0, β_1, β_2 – parameters of the production function.

In multi-factor production, the model expanded to the form:

$$Y = f(X_1, X_2, \ldots, X_n), \quad (2)$$

where Y – wheat yield, c/ha, X_n – variable costs by specific category, for example.

In the multi-factor analysis of wheat production, the production function included the following variable costs: X_1 – expenditures on fertilisers per hectare, thousand UAH; X_2 – expenditures on seeds per hectare, thousand UAH; X_3 – expenditures on contractor services per hectare, thousand UAH; X_4 – expenditures on fuel and lubricants per hectare, thousand UAH; X_5 – expenditures on labour per hectare, thousand UAH; X_6 – other material costs per hectare, thousand UAH and others.

Transition to financial indicators

Based on the production function, revenue from product sales was determined as:

$$TR(X) = P \cdot Y(X), \quad (3)$$

where $TR(X)$ – total revenue; P – price per unit of output; $Y(X)$ – yield function.

Marginal profit:

$$MP(X) = TR(X) - VC(X), \quad (4)$$

where $MP(X)$ – marginal profit per hectare, thousand UAH; $VC(X)$ – variable costs.

In the analysis of marginal profit per hectare in wheat production, the variable costs were defined as follows: X_1 – expenditures on fertilisers, thousand UAH/ha; X_2 – expenditures on seeds, thousand UAH/ha; X_3 – expenditures on contractor services, thousand UAH/ha; X_4 – expenditures on fuel and lubricants, thousand UAH/ha; X_5 – expenditures on labour, thousand UAH/ha; X_6 – other material costs, thousand UAH/ha and others. Net profit:

$$NP(X) = MP(X) - FC - INT(X) - TAX, \quad (5)$$

where $NP(X)$ – net profit per hectare, thousand UAH; FC – fixed costs; $INT(X)$ – interest expenses; TAX – taxes.

Credit servicing costs:

$$INT(X) = VC(X) \cdot \frac{r(X)}{2}, \quad (6)$$

where $INT(X)$ – interest expenses; $VC(X)$ – variable costs; $r(X)$ – average weighted credit rate.

It was assumed that own financing sources covered at least 50% of total resource needs, while credit covered a maximum of half of variable costs.

Operating leverage (DOL)

To evaluate the efficiency of budgeting variable costs, the degree of operating leverage was used:

$$DOL(X) = \frac{dNP(X)/dX}{dTR(X)/dX}, \quad (7)$$

where $DOL(X)$ – degree of operating leverage; $NP(X)$ – net profit; $TR(X)$ – total revenue.

In a multi-factor context (e.g., fertilisers (X_1) and seeds (X_2)):

$$DOL(X_1, X_2) = \frac{\frac{\partial NP}{\partial X_1} + \frac{\partial NP}{\partial X_2}}{P \cdot \left(\frac{\partial Y}{\partial X_1} + \frac{\partial Y}{\partial X_2}\right)}, \quad (8)$$

where X_1 – expenditures on fertilisers; X_2 – expenditures on seeds; P – price per unit of output; Y – yield.

In the multi-factor context, the degree of operating leverage (*DOL*) for wheat production was calculated using expenditures on fertilisers (X_1) and seeds (X_2). The *DOL* represented the sensitivity of net profit to changes in revenue and was defined as: X_1 – expenditures on fertilisers, thousand UAH/ha; X_2 – expenditures on seeds, thousand UAH/ha; 3,540 – wheat selling price, UAH/t; numerator – sum of marginal effects of expenditures on net profit; denominator – sum of marginal effects on revenue, calculated as the product of yield and price.

Financial elasticity

The second key indicator was the financial elasticity of profit with respect to the credit rate:

$$E_{NP,r}(X) = \frac{\Delta NP(X)/NP(X)}{\Delta r(X)/r(X)}, \quad (9)$$

where $E_{NP,r}(X)$ – financial elasticity of profit with respect to credit rate; $NP(X)$ – net profit; $r(X)$ – credit rate.

The financial elasticity of net profit with respect to expenditures on fertilisers (X_1) and seeds (X_2) reflected the sensitivity of net profit to changes in revenue resulting from variations in these input costs. The variables were defined as follows: $NP(X_1, X_2)$ – net profit function; $r(X_1, X_2) = P \cdot Y(X_1, X_2)$ – revenue depending on yield and price; X_1, X_2 – expenditures on fertilisers and seeds, respectively; $\partial NP/\partial X_i$ – marginal effect of expenditures on net profit; $\partial r/\partial X_i$ – marginal effect of expenditures on revenue. These definitions allowed for consistent computation of operating leverage (*DOL*) and financial elasticity across different input scenarios. To test stability, scenario analysis was applied with credit rate variation of ±20% from the baseline level.

Integration of indicators into the budgeting process

Operating leverage and financial elasticity form a complementary system of criteria that enabled the transition from static planning to scenario analysis: DOL evaluated the efficiency of the structure of variable costs in monetary terms; determined the resilience of financial results to changes in credit conditions. Their joint application ensured managerial control over the "result-risk" ratio and provided the foundation for constructing scenario-based budgets. For the calculation of operating leverage and financial elasticity, the variables were defined as follows: $NP(X_1, X_2)$ – net profit, thousand UAH/ha; $Y(X_1, X_2)$ – wheat yield, c/ha; X_1, X_2 – expenditures on fertilisers and seeds, respectively; numerator of the first fraction – total marginal effect of expenditures on profit, normalised to its level; denominator of the second fraction – corresponding marginal effect on revenue, ensuring unit consistency.

▸ Results

The analysis of grain production costs and their impact on yield was important for determining the optimal allocation of resources and assessing the associated financial risks. By integrating production modelling with financial indicators such as operating leverage and financial elasticity, it was possible to determine technical efficiency and economic stability. Technological optimisation of resource use, profit behaviour under different cost structures, and the financial stability of grain producers under different market conditions became key components in assessing the response of grain production to changes in resource supply. To empirically formalise these relationships and quantify the nonlinear effects of key production factors on grain yield, a multivariate quadratic regression model was constructed, which was expressed by the following production function:

$$Y = -41.14 + 16.5 \cdot X_1 + 95.7 \cdot X_2 - 1.55 \cdot X_1^2 - 56.2 \cdot X_2^2 - 3.67 \cdot X_3 - 5.76 \cdot X_4 + 13.62 \cdot X_5 + 5.31 \cdot X_6. \quad (10)$$

The quality of equation (10) was assessed as satisfactory: the coefficient of determination equaled ($R^2 = 0.606$), the adjusted ($R^2 = 0.409$), and the F-statistic value of 3.073 with ($p = 0.027$) confirmed the statistical significance of the model as a whole. The standard error of residuals was 7.12, indicating an acceptable level of forecast accuracy. At the same time, despite the moderate explanatory power, the model primarily performed an analytical function – it allowed for quantitative assessment of the impact of individual cost components on production performance and determination of optimal proportions of their use, at which maximum yield was achieved. The estimated parameters confirmed the appropriateness of the parabolic specification: linear coefficients for fertilisers and seeds were positive, while quadratic coefficients were negative, reflecting the law of diminishing returns. Based on this, the local optimum of expenditures was calculated, at which yield reached its maximum. The calculations showed that the optimal values were approximately 5.3 thousand UAH/ha for fertilisers and 0.85 thousand UAH/ha for seeds. At the same time, the local optimum was determined under the condition of fixing other factors at their average levels: expenditures on contractor services – 0.85 thousand UAH/ha, fuel and lubricants – 0.99 thousand UAH/ha, labour – 0.78 thousand UAH/ha, and other material costs – 1.88 thousand UAH/ha. At the point of maximum, the predicted wheat yield was 55.1 c/ha, which confirmed the practical significance of the model and its suitability for optimising production decisions (Fig. 1).

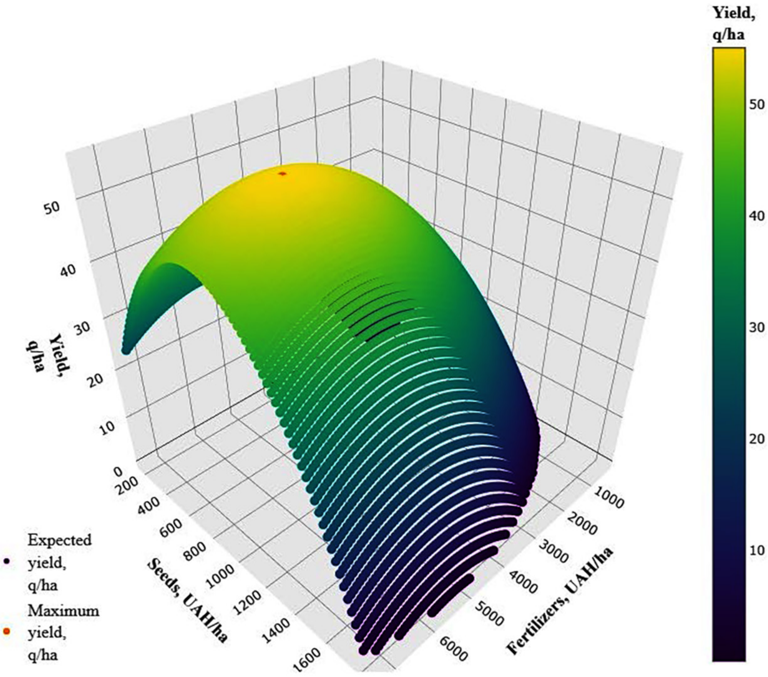

Figure 1. Dependence of wheat yield on expenditures for fertilisers and seeds
Notes: the yellow marker indicated the local maximum point of 55.1 c/ha
Source: State Statistics Service of Ukraine (2021)

Results represented the level of technological efficiency that an enterprise can achieve under a rational structure of variable costs. Thus, equation (10) reflected not only the production logic of the agricultural process but also created prerequisites for integrating financial indicators into the cost budgeting system, forming the basis for further scenario analysis and assessment of enterprise resilience. To evaluate the economic efficiency of production, a marginal profit function was constructed, which integrated variable costs and the selling price into the yield production function. The yield function was multiplied by the average selling price of third-class wheat grain in Ukrainian agricultural enterprises in 2020, which, according to the State Statistics Service of Ukraine (2021), amounted to 354 UAH/c. Revenue was then reduced by the amount of variable costs. After expanding the brackets and simplifying the coefficients, the formula for marginal profit as a function of variable costs at a fixed selling price took the form:

$$MP = -14.56 + 4.84 \cdot X_1 + 32.87 \cdot X_2 - 0.55 \cdot X_1^2 - 19.91 \cdot X_2^2 - 2.30 \cdot X_3 - 3.04 \cdot X_4 + 3.82 \cdot X_5 + 0.88 \cdot X_6. \quad (11)$$

Based on the constructed model, the local optimum of marginal profit was determined. The calculations showed that the maximum marginal profit was achieved under the following expenditure parameters: fertilisers – 4.40 thousand UAH/ha, seeds – 0.82 thousand UAH/ha, contractor services – 0.85 thousand UAH/ha, fuel and lubricants – 0.99 thousand UAH/ha, labour – 0.78 thousand UAH/ha, and other material costs – 1.88 thousand UAH/ha. At this optimum point, the predicted yield was 53.8 c/ha, variable costs amount to 9.73 thousand UAH/ha, and the maximum marginal profit was 9.32 thousand UAH/ha. The transition from physical results (equation 10) to monetary results (equation 11) through the inclusion of the price factor caused a shift in the expenditure optimum. As a result, the yield level at the point of maximum marginal profit was 53.8 c/ha, which was 1.3 c/ha lower than at the maximum of the production function yield (55.1 c/ha). The shift of the optimum towards lower yield was explained by the fact that the maximisation criterion accounted not only for the physical volume of production but also for the marginal effect of costs directly influencing revenue. The next step was to account for the enterprise's fixed costs, which allowed the transition from marginal profit to net profit. Considering the average level of fixed costs of 3,858 thousand UAH/ha, including depreciation, overhead, and administrative expenses per hectare, the net profit function took the form:

$$NP = -18.418 + 4.84 \cdot X_1 + 32.87 \cdot X_2 - 0.55 \cdot X_1^2 - 19.91 \cdot X_2^2 - 2.30 \cdot X_3 - 3.04 \cdot X_4 + 3.82 \cdot X_5 + 0.88 \cdot X_6. \quad (12)$$

The calculations showed that at the local optimum point, the predicted net profit was 5.46 thousand UAH/ha, which was almost 41% lower than the maximum marginal profit (9.32 thousand UAH/ha). This level of net profit can be used as a target value in the formation of production unit budgets (Fig. 2).

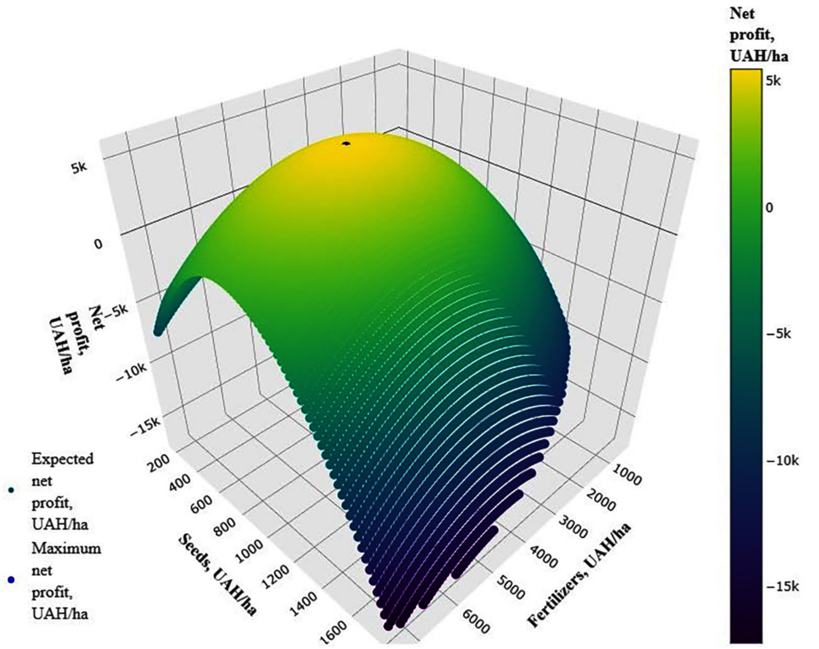

Figure 2. Dependence of net profit from wheat production and sales on expenditures for fertilisers and seeds
Notes: the blue marker indicated the local maximum point corresponding to a net profit level of 5.46 thousand UAH/ha at a yield of 53.8 c/ha
Source: State Statistics Service of Ukraine (2021)

Model (12) not only reflected the financial logic of the agricultural process but also created prerequisites for integrating the net profit indicator into managerial budgeting systems. This formed the basis for further scenario analysis and assessment of enterprise resilience under changing market conditions. Determining the local optimum of net profit allowed for evaluation of the final financial outcome of production. However, for comprehensive analysis it was important to consider not only absolute profit values but also the sensitivity of financial indicators to changes in cost structure. In this context, the key role was played by the operating leverage (DOL) indicator, defined as the ratio of marginal profit to net profit, which characterised the degree of risk associated with fluctuations in revenue or costs. The operation of the law of diminishing returned in grain production determined the choice of a parabolic production function, which implied that any deviation of the cost structure from the optimum unevenly affects performance. This nonlinearity transformed the behaviour of operating leverage: the DOL indicator became sensitive not only to fluctuations in revenue but also to the position of the enterprise along the production curve. Accordingly, budgeting of variable costs must account not only for their level but also for their position relative to the technological optimum point, forming a risk management logic through control of cost structure. To formalise this effect, a modified analytical form of the operating leverage indicator was used, which considered the marginal impact of expenditures on fertilisers and seeds both on net profit and on revenue. Taking into account the functional relationship of yield with expenditures (equation 10), as well as the dependence of net profit on yield (equation 12), the DOL indicator took the form:

$$DOL(X_1, X_2) = \frac{37.71 - 1.10 \cdot X_1 - 39.82 \cdot X_2}{3{,}540 \cdot (112.2 - 3.10 \cdot X_1 - 112.4 \cdot X_2)}. \quad (13)$$

Calculations based on the model showed that the maximum value of operating leverage reaches 9.99 at expenditures on fertilisers of 4.47 thousand UAH/ha and on seeds of 1.33 thousand UAH/ha (Fig. 3). At this point, the predicted yield was 41.2 c/ha, marginal profit – 4.29 thousand UAH/ha, and net profit – only 0.43 thousand UAH/ha. Such a DOL level was critically high: minimal deviations in revenue or costs can cause a sharp reversal of financial results, indicating increased operational instability.

High values of operating leverage in this case were a direct consequence of the enterprise entering a zone of low technological returns, where additional expenditures no longer provide proportional yield increases.

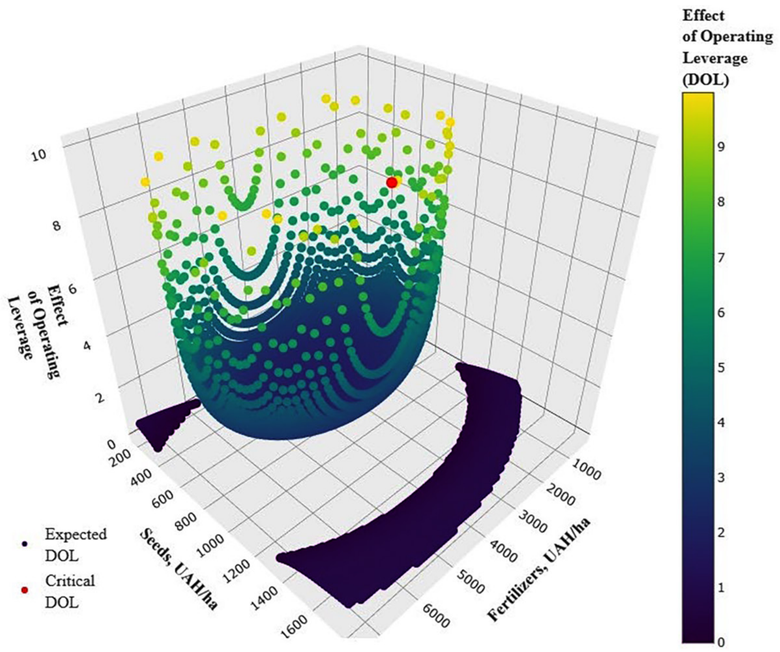

Figure 3. Dependence of operating leverage on expenditures for fertilisers and seeds

Notes: the red marker indicated the local maximum point of operating leverage (9.99) at a net profit of 0.43 thousand UAH/ha

Source: State Statistics Service of Ukraine (2021)

From a managerial perspective, it was advisable to focus on a moderate range of operating leverage – 1.1-1.6. This range was achieved at expenditures on fertilisers of 3.5-4.0 thousand UAH/ha and on seeds of 0.8-0.9 thousand UAH/ha. Within this interval, the predicted yield was 53-54 c/ha, and net profit was approximately 5.0-5.5 thousand UAH/ha, ensuring a balance between profitability and stability. Such a zone of operating leverage reflected a rational "result-risk" ratio and was appropriate for budgeting variable costs. It formed the basis for managerial control aimed at minimising operational risks, while maintaining the target level of profitability. Thus, budgeting variable costs in grain production must account not only for the absolute level of resources but also for their position relative to the technological optimum. The use of a parabolic specification of the production function made it possible to identify "safe zones" of investment in fertilisers and seeds, where financial risk was minimal and the effect of additional expenditures was predictable. This created the foundation for scenario-based budgets and the integration of sensitivity indicators (DOL) into the system of managerial control of agricultural enterprises' financial results.

Alongside the influence of variable cost structure on operating leverage, an important element of the financial strategy of agricultural producers was assessing how changes in external financial conditions transformed the final outcome. Since seasonal production largely relied on short-term credit, the interest rate became not merely a parameter of borrowing costs but a factor capable of shifting the optimal balance point between expenditures and expected yield. In this context, a logical continuation of the analysis was the determination of the elasticity of net profit with respect to changes in the interest rate. The cost of credit affects performance through two channels: directly – via increased debt servicing costs, and indirectly – through the transformation of optimal combinations of fertilisers and seeds in the production function. As a result, an increase in the interest rate narrowed the space of resource combinations, in which the enterprise can ensure positive net profit, justifying the need for credit elasticity analysis as the final stage of the study. For a multi-factor model, where revenue was formed as the product of yield and selling price, and yield itself was a function of expenditures on fertilisers (X_1) and seeds (X_2), the financial elasticity indicator was defined as:

$$E_{NP,r}(X_1,X_2) = \frac{\frac{\partial NP(X_1,X_2)}{\partial X_1}+\frac{\partial NP(X_1,X_2)}{\partial X_2}}{NP(X_1,X_2)} \cdot \frac{r(X_1,X_2)}{\frac{\partial r(X_1,X_2)}{\partial X_1}+\frac{\partial r(X_1,X_2)}{\partial X_2}}. \quad (14)$$

In a specified form, this formula became:

$$E_{NP,r}(X_1,X_2) = \frac{37.71-1.10X_1-39.82X_2}{NP(X_1,X_2)} \cdot \frac{Y(X_1,X_2)}{112.2-3.10X_1-112.4X_2}. \quad (15)$$

Thus, the financial elasticity indicator made it possible to assess how a percentage change in revenue translated into a percentage change in net profit depending on cost structure and credit conditions. It served as an indicator of enterprise financial resilience and complemented the analysis of operating leverage. The combined application of these two indicators within a methodological system allowed not only the determination of absolute profit levels but also the assessment of their sensitivity to changes in cost structure and credit resource costs, forming the basis for risk management and improving the efficiency of budgeting in grain production. To reveal the effect of financial elasticity, scenario analysis was conducted, in which the credit rate varied within ±20% of the baseline level. The results demonstrated pronounced spatial heterogeneity of net profit elasticity with respect to the interest rate (E_r) in the "fertilisers-seeds" plane. The maximum elasticity value (E_r = 0.10) was recorded at expenditures on fertilisers of about 1.9 thousand UAH/ha and expenditures on seeds of approximately 0.53 thousand UAH/ha (Fig. 4).

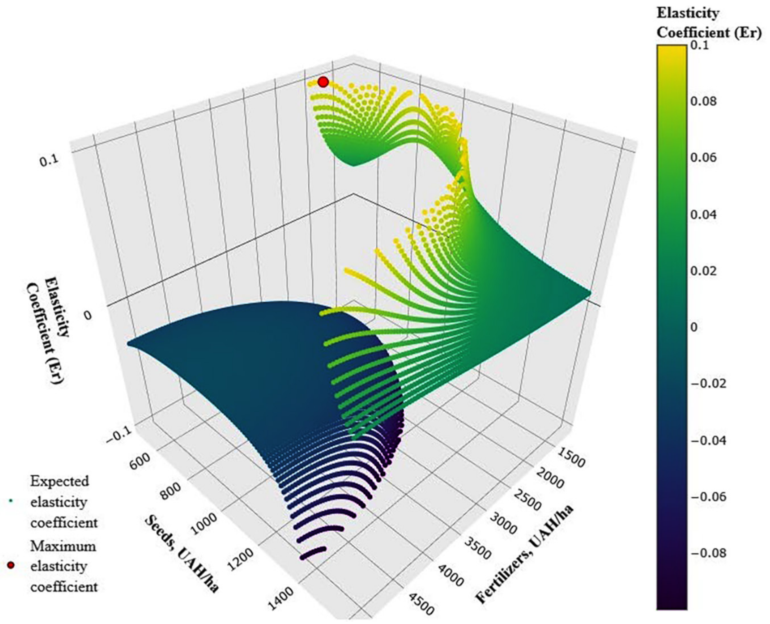

Figure 4. Dependence of the financial elasticity coefficient on expenditures for fertilisers and seeds
Notes: red marker indicated the local maximum point of the financial elasticity coefficient (0.10), at which the financial result amounted to -1.32 thousand UAH/ha
Source: State Statistics Service of Ukraine (2021)

It was indicated that yield was about 31.3 c/ha, and net profit was negative (-1.32 thousand UAH/ha). This meant that the zone of highest profit sensitivity to the credit rate coincided with the regime of technological underfunding, when resources were applied at a level insufficient to achieve economies of scale and avoid the law of diminishing returns. In such a regime, the enterprise operated "on the lower branch" of the production function, where each unit of resource still provides high marginal returns, but the baseline yield level was insufficient to cover fixed and financial costs. Overall, the analysis demonstrated that combining production and financial models allowed for a more comprehensive assessment of risk contours in agricultural production. The constructed quadratic production function revealed the technological optimum and identified the zone of rational budgeting of variable costs, while the evaluation of operating leverage showed how deviations from this optimum amplified financial instability of the enterprise. Additional consideration of net profit elasticity with respect to credit resource costs confirmed that sensitivity to the interest rate strongly depended on the enterprise's position on the production curve: in the zone of technological deficit, financial vulnerability increased sharply, whereas in the range of optimal expenditures a stable profitability profile was formed even under deteriorating credit conditions. Thus, the results of the study confirmed that effective budgeting of variable costs cannot be carried out in isolation from debt burden management. Decisions regarding cost structure and borrowing must be made in interconnection, since technological and financial risks reinforced each other. This created the foundation for developing an integrated financial strategy for agricultural enterprises, in which optimisation of the production cost structure, evaluation of operating leverage, and analysis of sensitivity to interest rate risk formed a unified system of managerial decision support.

▸ Discussion

The results obtained in this study provided a detailed quantitative assessment of the interrelationships between resource allocation, wheat yields, and financial indicators in grain production, situating the findings within the broader context of agricultural economics and farm management research. The constructed quadratic production function captured the nonlinear response of wheat yield to variable input expenditures, a characteristic feature emphasised in numerous empirical and theoretical studies. C.L. Escalante & P.J. Barry (2001) highlighted that effective farm management required the integration of production efficiency with financial constraints, particularly in environments characterised by input cost volatility. This interpretation is further supported by P.J. Barry & P.N. Ellinger (2012), who argued that agricultural financial management must simultaneously evaluate production decisions, liquidity, solvency, and risk-bearing capacity. The present results aligned with these conclusions by demonstrating that deviations from optimal resource allocation significantly amplified financial sensitivity, especially under conditions of technological underfunding.

B.-L. Miao *et al.* (2023), employing a portfolio optimisation approach to crop resource allocation, argued that the maximisation of physical output does not necessarily guarantee financial optimality, as cost interactions and price volatility often shift the economically efficient input combination away from the technological optimum. The findings of this study confirmed this divergence, revealing that the financially optimal combination of fertiliser, seed, and service expenditures differed from the point of maximum yield. In particular, under constrained resource conditions, technological optima failed to ensure adequate coverage of fixed and interest-related costs, reinforcing the necessity of integrated production-financial planning frameworks. F. Akhavizadegan *et al.* (2022) applied stochastic optimisation to farm management under uncertainty and demonstrated the critical role of scenario analysis in identifying risk-sensitive resource combinations. The methodology adopted in this research complemented this approach by operationalising scenario-based evaluation through indicators of operating leverage (DOL) and financial elasticity of net profit with respect to credit rates. The importance of evaluating credit conditions in agricultural production was also emphasised by V. Hmyrya (2017), who demonstrated that financial viability depends substantially on the structure and cost of borrowed capital. The results showed that enterprises operating below the technological optimum exhibited substantially higher vulnerability to interest rate increases, whereas those operating near the optimum maintained relatively stable profitability even under moderate financial shocks. This correspondence underscored the practical relevance of scenario-based modelling for agricultural financial planning.

M. Hernandez-Romero & G. Coenders (2025) analysed the resilience of agricultural enterprises to external shocks and concluded that balanced cost structures and moderate debt levels were crucial for sustaining financial stability. Consistent with this perspective, the present study demonstrated that the combination of optimal resource allocation and rational credit utilisation formed a protective buffer against financial stress. Estimates of financial elasticity confirmed that sensitivity to borrowing costs declined significantly near the technological optimum, providing empirical justification for integrating production modelling with capital structure decisions. Empirical evidence provided by Rissi & Herman (2021) similarly confirms that liquidity, profitability, and financial leverage are key predictors of financial distress, reinforcing the conclusion that excessive leverage amplifies vulnerability under volatile income conditions. The findings also extend the conceptual framework proposed by O. Kochetkov & J. Afanasova (2020), who developed a mechanism for managing the resource potential of agricultural enterprises. Their approach stressed that efficient allocation and utilisation of material, labour, and financial resources were prerequisites for sustainable enterprise development. The quantitative modelling implemented in this study operationalised this concept by explicitly linking resource inputs with yield response, marginal profitability, and financial sensitivity. This integration enabled a deeper understanding of how resource potential translated into financial performance under different economic scenarios, thus bridging a key gap between resource management theory and applied financial analysis.

Moreover, the results contributed to the debate on conservative financial strategies in volatile environments, as discussed by F. Morais *et al.* (2021) in their analysis of the zero-leverage phenomenon. Their study suggested that firms often deliberately avoided debt to mitigate financial risk, particularly under unstable market conditions. In the context of grain production, this research demonstrated that while excessive leverage amplifies financial sensitivity, complete avoidance of debt may also constrain technological optimisation and limit yield potential. Hence, the findings supported a balanced financial strategy, in which moderate leverage, aligned with optimal resource allocation, enhances both production efficiency and financial resilience.

From a strategic planning perspective, N.I. Okeke *et al.* (2024) emphasised the central role of integrated budgeting and revenue management systems in forecasting financial stability, particularly in small and medium-sized enterprises. The scenario-based budgeting framework developed in this study directly complemented their conclusions by offering a quantitative tool for forecasting profit volatility, liquidity risks, and credit sensitivity under alternative resource and price scenarios. This enabled managers to evaluate not only expected profitability but also downside risk, thereby improving the robustness of financial planning. In line with international policy perspectives, the OECD (n.d.) stresses that agricultural risk management should combine production risk mitigation, financial instruments, and strategic planning tools. The integrated modelling framework proposed in this study corresponds directly to this multidimensional view of agricultural risk governance.

V. Zdir *et al.* (2019) stressed that empirical yield and cost data were indispensable for constructing effective financial strategies in agriculture. By integrating actual expenditure data on fertilisers, seeds, labour, fuel, and contractor services, the models developed in this research generated concrete estimates of marginal productivity, operating leverage, and financial elasticity across different input combinations. This approach provided a granular assessment of both efficiency and risk, consistent with the empirical emphasis advocated by V. Zdir *et al.* (2019). Global statistical evidence provided by FAO (2021) further confirms that fluctuations in yields, input prices, and production costs remain among the most influential determinants of farm income variability worldwide. The present study bridged these macroeconomic insights with micro-level modelling, demonstrating that operational and financial risks were deeply interconnected, particularly under resource-constrained conditions.

Collectively, the comparative analysis of these sources yielded several key insights. Firstly, the nonlinear response of grain yield to variable inputs was consistently observed across different geographical and methodological contexts. Secondly, financial sensitivity was highly contingent on both resource allocation and debt structure, underscoring the necessity of joint consideration of production and financial parameters. Thirdly, scenario-based and stochastic modelling approaches proved effective in identifying risk-prone input combinations, thereby supporting more resilient budget planning. By explicitly quantifying the effects of individual inputs on yield, marginal profit, and net profit, this study extended prior research by offering a direct operational framework for scenario analysis in grain production. The incorporation of operating leverage and financial elasticity established a conceptual and analytical bridge between production efficiency and financial resilience. Findings demonstrated that enterprises operating below the technological optimum experience amplified negative effects from interest rate increases, while those operating near the optimum maintain greater financial stability. This reinforced the principle that maximising physical output alone is insufficient; financial planning must systematically account for cost structures, marginal efficiencies, and exposure to external shocks.

Overall, the proposed modelling framework provides a robust foundation for strategic resource planning, financial risk management, and adaptive budgeting in grain production under volatile market conditions. By integrating technological and financial dimensions, the study offers practical guidance for managers and policymakers seeking to enhance the sustainability and competitiveness of agricultural enterprises.

Conclusions

The study confirmed that the use of a parabolic production function was an adequate tool for modelling the technological behaviour of grain production and for further integration of its results into the financial planning system. The estimated yield function made it possible not only to establish the impact of individual cost items on productivity but also to determine the local optimum of their combination. With a rational structure of variable costs, the enterprise was capable of achieving a forecasted yield of 55.1 c/ha, which defined its technological efficiency. The transition to monetary indicators through the construction of marginal and net profit functions showed that the optimum of financial results does not coincide with the optimum of yield. At the point of maximum marginal profit, yield was lower (53.8 c/ha), reflecting the effect of marginal costs not accounted for in the physical model. The inclusion of fixed costs narrowed the area of economically feasible resource combinations, while the maximum net profit of 5.46 thousand UAH/ha outlined the real financial potential of production under rational budgeting. The analysis of the operating lever proved that its maximum values were formed in the zone of technological underfunding and were accompanied by a minimum or almost zero net profit, which indicated a high level of risk and instability of such regimes. In contrast, the safe and manageable operating leverage range of 1.1-1.6 corresponded to moderate expenditures on fertilisers and seeds and ensured stable profitability. The study of financial elasticity of net profit with respect to the interest rate revealed that the greatest credit risk was borne by enterprises operating in a resource underfunding regime. In this zone, even moderate increases in credit costs led to deepening losses due to the combination of low yields, uncovered fixed costs, and rising financial expenses. Thus, the credit rate in grain production acted not merely as a financial parameter but as a factor that changed the optimal proportions of resource use and transformed the "profitability landscape". Future studies can focus on refining scenario-based budgeting models, exploring the impact of credit and input price volatility on profitability, and developing adaptive strategies that enhanced the resilience of agricultural enterprises to both technological and financial risks.

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Conflict of Interest

None.

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Вплив операційного важеля та фінансової еластичності на бюджетування змінних витрат у виробництві зерна

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▶ **Анотація.** Стійкість фінансових стратегій в аграрних підприємствах залежить від точного прогнозування параметрів виробництва та супутніх кредитних ризиків в умовах нестабільного ринку. Метою цього дослідження було оцінити технологічну реакцію виробництва зерна на зміни у постачанні ресурсів і інтегрувати результати у прогнозування ліквідності та оцінку ризику негативних процентних ставок. Оцінена квадратична виробнича функція адекватно відображала нелінійну реакцію врожайності пшениці на змінні витрати, підтверджуючи закон спадної граничної віддачі. Модель продемонструвала задовільну статистичну ефективність ($R^2 = 0{,}606$, скориговане $R^2 = 0{,}409$) та була статистично значущою ($F = 3{,}073$, $p = 0{,}027$). Виявлений технологічний оптимум відповідав максимальному прогнозованому врожаю 55,1 ц/га, досягнутому при витратах на добрива і насіння приблизно 5,3 та 0,85 тис. грн/га відповідно. При застосуванні показників на основі вартості оптимум змістився в бік максимізації прибутку. Максимальний граничний прибуток досяг 9,32 тис. грн/га при трохи нижчих рівнях витрат, з відповідним врожаєм 53,8 ц/га, тоді як максимальний чистий прибуток склав 5,46 тис. грн/га після врахування постійних витрат. Аналіз операційного важеля виявив виражену нелінійність фінансової чутливості. Надзвичайно високі значення DOL (до 9,99) спостерігались в умовах недофінансованого виробництва, де чистий прибуток наближається до нуля, що вказує на критичну операційну нестабільність, в той час як стабільний діапазон DOL 1,1-1,6 відповідав помірним рівням витрат. Аналіз сценаріїв кредитних умов (±20 % зміна процентної ставки) показав асиметричний ризик процентної ставки. Найвища фінансова еластичність чистого прибутку ($E \approx 0{,}10$) спостерігалась у низьковитратних, збиткових режимах, тоді як поблизу технологічного оптимуму еластичність наближається до нуля, що свідчить про відносну фінансову стійкість. Результати підтвердили, що інтеграція виробничого моделювання з показниками фінансової чутливості покращує прогнозування ліквідності та кредитне планування в зерновому виробництві

▶ **Ключові слова:** параболічна виробнича функція; оптимізація ресурсів; граничний прибуток; ліквідність; ризик процентної ставки; фінансове планування