The competitiveness of machine-building enterprises: current state and prospects for development

Mariia Samofalova[1], *Natalia* Karachyna[2], Anna Slobodianyk[3], *George* Abuselidze[4,*], *Oleksandr* Khadartsev[5], and *Yuriy* Ruban[6]

[1] Open International University of Human Development «Ukraine», Lvivska, 23, Kyiv, 03115, Ukraine
[2] Vinnytsia National Technical University, Khmel'nyts'ke Hwy, 95, Vinnytsia, 21000, Ukraine
[3] National Aviation University, Lubomir Husar, 1, Kyiv, 03085, Ukraine
[4] Batumi Shota Rustaveli State University, Ninoshvili, 35, Batumi, 6010, Georgia
[5] National University «Yuri Kondratyuk Poltava Polytechnic», Pershotravneva, 24, Poltava, 36011, Ukraine
[6] National Research Center "Institute of Agrarian Economics", Heroiiv Oborony, 10, Kyiv, 03127, Ukraine

Abstract. Today, in the context of a full-scale invasion, the post-war reconstruction of the national economy requires determining the place and role of enterprises of the machine-building industry with further assessment of the prospects for their development since the machine-building complex is considered to be one of the most innovative segments of any national economy and includes enterprises of the military-industrial complex. Mechanical engineering is one of the leading industries in Europe and the world. For example, the industry produces about 9.1% of all manufacturing output in the European Union. The share of value added in the total manufacturing industry is higher than in manufacturing, at around 11.5%. Despite the importance of this industry, domestic machine building accounts for only 7% of total industrial output and 2% of gross value added to Ukraine's GDP. It is crucial to thoroughly research the potential for advancing the country's machine-building complex, as it is a vital component of the industry and a key element in strengthening the state's defence capabilities. The article aims to scientifically substantiate methodological and methodical approaches to assessing the competitiveness of machine-building enterprises in Ukraine, their identification by individual categories, and rating economic entities based on an integral indicator of competitiveness with modelling of forecast indicators of their development. The research methodology is based on data from machine-building enterprises in Ukraine (4 years and 38 manufacturers of the industry), processed using statistical analysis and economic and mathematical models to forecast their competitiveness in the short term.

[*] *Corresponding author: george.abuselidze@gmail.com*

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1 Introduction

As of the beginning of 2020, machine building accounted for more than 22% of the industry's fixed assets, employing more than 300,000 people (almost 18% of the total number of full-time employees in the industrial sector of Ukraine). Ukraine produced more than 3,500 items of machinery and equipment of the main types of machine-building complex: heavy, energy, agricultural, precision, railway engineering, as well as tractor, machine tool, automotive, shipbuilding and aerospace industries.

Mechanical engineering is one of the leading industries in Europe and the world. In particular, an analytical study by Karachyna [1] showed that the industry produces about 9.1% of all manufacturing products in the European Union. As noted by Kushnirenko and other scholars, the share of value added in the machine building industry in the total volume of the manufacturing industry is higher than in manufacturing. It amounts to about 11.5% [2].

Ukraine's share in the pre-war world trade in mechanical engineering products was already insignificant: 0.07% in exports and 0.19% in imports. For example, in 2017, Ukraine's highest positions in the world were in the electrical equipment for motor vehicles (1.77%), railway rolling stock (0.97%) and electrical household appliances (0.27%).

The structure of domestic exports also underwent negative changes for machine-building products after 2013, when their share began to decline from 16.3% to 11.5% in 2016, as noted by Mikhalchenko and other scholars in [3]. Agricultural commodity exports received significant direct and indirect state support in the last pre-war years [4-].

Due to the hostilities, exports of Ukrainian machine-building products lost about 2/3 of their 2021 value. The loss of production capacity in 2022 was offset by an increase in imports, indicating an increase in import dependence in the domestic market. In general, it is the heavy industry that will suffer the most significant losses in terms of exports. For example, exports of Ukrainian machine-building products dropped by almost 90% and metallurgy by 65%. For comparison, Ishchuk and Lozansky found that the decline in exports of the agricultural and agro-industrial industry was only about 30%, and the furniture industry - about 40% [ ].

Thus, the above studies show that it is impossible to assess the competitiveness of machine-building enterprises in the foreign market since the share of their products worldwide and domestic exports is relatively low. We must note that it is also impossible to assess the competitiveness of machine-building enterprises in the structure of the national economy, given the significant reduction in the share of their products in the gross domestic product (7% in the structure of industry and 2% of gross value added in the GDP of Ukraine).

Therefore, we propose estimating enterprises' competitiveness level in the intra-industry structure and ranking individual components of the machine-building complex to identify the most competitive ones. According to the Classifier of Economic Activities of Ukraine, the machine-building industry is divided into five groups, in particular:

Group 1 - 26 «Manufacture of computers, electronic and optical products».

Group 2 – 27 «Manufacture of electrical equipment».

Group 3 - 28 «Manufacture of machinery and equipment n.e.c».

Group 4 - 29 «Manufacture of motor vehicles, trailers and semi-trailers and other vehicles».

Group 5 – 30 «Manufacture of other vehicles. Manufacture of other vehicles».

Therefore, this study aims to determine the level of competitiveness of machine-building enterprises by the above groups (categories) according to the classifier of economic activities in Ukraine, namely to identify enterprises belonging to the five groups

of industry components for further determination of the most competitive ones and prospects for their development in the future.

The world's theoretical heritage in the theory of competitiveness is the scientific research of M. Porter, who established the general principles of competitiveness at both the industry and enterprise levels [ ]. One of the new approaches to determining the competitiveness of business structures is the benchmarking method, which has become widespread in foreign practice. Foreign scientists such as Darrell [1 and Bruckhardt [1] have studied theoretical aspects of benchmarking. According to Darrell, benchmarking is a method that increases the productivity of an enterprise by identifying and implementing the best practices of economic operations and sales of companies [ ]; Bruckhardt believes that benchmarking is a type of activity related to customers, technology and business culture and is carried out in planning with a focus on value creation and competence [1].

In the scientific work, Vargas-Chanes [1] and other scholars proposed a new tool for measuring the competitiveness of travel service companies. The tool summarises seven indicators: characteristic and tourism vocation, routine and process management, continuous improvement management, human capital management, market customer management, social impact and development capability, and benefits assessment.

I. Maslani and other scholars in their work [1] identify such criteria of company competitiveness as flexibility and sustainability, which are vital for measurement. It is believed that the speed and sustainability of the company are two of the most important indicators of the competitiveness of a state-owned enterprise; in particular, enterprises' dynamic and marketing capabilities are primarily affected.

In their scientific work [1], Phetphongphan and Mumi proposed three main factors for improving dynamic corporate competitiveness: the ability to adapt strategically, excellence in achieving goals, and fulfilment of stakeholder expectations.

It is worth noting that human resources are equally crucial for machine-building enterprises. Jaimes-Acero and other authors' idea of using ten soft skills should give college graduates greater competitiveness in engineering [1]. Bachelor's and Master's degree programmes should incorporate these new business requirements into their curricula to increase graduates' competitiveness and future workforce effectiveness.

The rapid development of technology makes it possible to use artificial intelligence methods to improve the competitiveness of machine-building enterprises. In particular, Mahat and other researchers in [1] suggest using artificial intelligence algorithms as powerful tools to improve supply chain operations and logistics in the machine-building industry.

The work of Nurmukhametova [1] on the state and mechanical engineering problems in the Republic of Kazakhstan is worthy of attention. The author compares the machine-building sector in Kazakhstan and other countries; analyses the current economic situation and identifies the characteristics and shortcomings of the machine-building sector of the respective countries; identifies the factors contributing to the growth rate of machine-building products; and identifies the main constraints for further successful development of the machine-building industries; the article assesses the progress of structural transformations in the machine-building industry based on data on the production of significant types of equipment and machinery for industry, which can serve as an algorithm for conducting similar studies in Ukraine.

The authors contributed significantly to the study of machine-building development in Ukraine [1]. The focus is on scientific support for representatives of the machine-building industry, which tend to be environmentally responsible. The financial and environmental indicators are presented in the results section based on six analysis groups of machine-building enterprises: large unstable - 16; large stable - 17; medium unstable - 44; medium stable - 26; small unstable - 188; small stable - 46. According to the authors, the

environmental factor is increasingly considered by Ukrainian innovative machine-building enterprises so that they can be competitive [1]. At the same time, the approach to assessing the competitiveness of machine-building enterprises by the criterion of the chosen model of economic behaviour, presented by Karachyna and other researchers in their scientific paper [ ], is quite interesting.

This article's scientific problem is the need to study the competitive development of machine-building enterprises, which will create preconditions for developing the national economy and increase Ukraine's defence capability. The article's hypothesis has both a theoretical and applied basis for assessing the competitive positions of the machine-building industry's components (groups). The article intends to intensify the introduction of innovative technologies by specific categories of machine-building enterprises based on the adopted regulatory and legal framework for their state support.

This study aims to provide scientific substantiation of methodological and methodical approaches to assessing the competitiveness of machine-building enterprises in Ukraine, their identification by individual categories and rating of business entities based on an integral indicator of competitiveness with modelling of forecast indicators of their development.

The study's object is the competitive development of machine-building enterprises in Ukraine. Its subject is determining the competitiveness of business entities in the machine-building industry and forecasting their development based on economic and mathematical models, which will contribute to the socio-economic growth of the national economy and the country's security.

The study consists of the following parts: firstly, the theoretical and applied basis based on the calculation of financial indicators of activity of machine-building enterprises of Ukraine is presented; secondly, methodical recommendations for assessing the level of competitiveness of enterprises in the industry are defined and improved; thirdly, integral indicators of the level of competitiveness of specific categories of machine-building enterprises are calculated; fourthly, the most reliable models for forecasting the levels of competitiveness of economic entities are determined.

The study's practical significance lies in its results, which can be used to adopt relevant regulatory documents on the State support of specific categories of machine-building enterprises in Ukraine as a significant factor in improving its defence capability.

2 Research Methods

The research methodology is based on data from Ukrainian machine-building enterprises that were processed by statistical analysis. The authors collected data on the financial position and various performance indicators (14 in total) directly from the financial statements. The research period is four years: 2020-2023; the number of machine-building enterprises - 38. The analysis included the following data: production and labour productivity, income and expenses, profitability, return on sales and capital, condition of fixed assets, indicators of financial stability and solvency, sales and labour efficiency, and social efficiency.

The basis was the integral approach to calculating the level of competitiveness of enterprises proposed by V. Oberemchuk, which takes into account the weight of the criteria using the geometric mean [19]:

$$K_p = \sqrt[8]{0{,}22P_1 \times 0{,}14P_2 \times 0{,}10P_3 \times 0{,}19P_4 \times 0{,}14P_5 \times 0{,}07P_6 \times 0{,}04P_7 \times 0{,}10P_8}$$

P_1 – product competitiveness;
P_2 – financial position of the company;
P_3 – efficiency of sales and promotion of goods;
P_4 – production efficiency;
P_5 – competitive potential;
P_6 – environmental friendliness of production;
P_7 – social efficiency;
P_8 – company image.

The financial and economic indicators are analysed using five categories of machine-building enterprises following the classifier of economic activities. These categories of enterprises are used to determine their level of competitiveness and calculate forecast values.

In our study, we substantiate and use an intra-industry methodological approach and individual author's criteria (labour efficiency is included in the integral indicator instead of competitive potential) and partial indicators for assessing the competitiveness of business entities in the machine-building industry (the growth rate of net sales revenue in assessing the image of an enterprise, for example), which makes it possible to rank enterprises and forecast their development in the short term.

3 Discussion

3.1 Improving methodological recommendations for assessing the competitiveness of machine-building enterprises

An intra-sectoral methodological approach to assessing the competitiveness of machine-building enterprises has been proposed and substantiated. Based on the carried out research [20], the following criteria and partial indicators of the integrated assessment of the level of competitiveness of enterprises in the machine-building industry have been proposed in particular:

- the criterion for the efficiency of the company's production activities: a comprehensive indicator that includes net income from sales of products, labour costs, working capital, and fixed assets;
- the criterion that characterises the financial condition of the company: depreciation, solvency, autonomy, return on equity and capital turnover ratios;
- labour efficiency criterion is a comprehensive indicator that includes labour productivity and labour costs;
- the criterion that reflects the efficiency of the sales organisation: the ratio of profitability of sales costs and profitability of sales;
- the criterion of product competitiveness is not significant for machine-building enterprises since enterprises produce original (non-competitive in the domestic market) products within a specific group and, therefore, is taken as a unit for all categories;
- social efficiency criterion: average salary growth rate, share of unified social tax in total net sales revenue;
- the criterion of environmental friendliness of production is not significant for machine-building enterprises since they do not pay environmental tax, and therefore is taken as one for all categories;
- image criterion: net sales revenue growth rate.

This list of criteria and relevant indicators is the most appropriate and objective for assessing enterprises regarding intra-industry competitiveness, in contrast to the basic methodology proposed by Oberemchuk [19].

3.2 Determination of indices of competitiveness of machine-building enterprises

It is essential to note that the indicators used in the above calculations cannot be consolidated into one criterion. For example, according to the methodological recommendations, the assessment of such a criterion as the financial condition of an enterprise is based on the calculation of the autonomy ratio and return on equity, which have different units of measurement. Therefore, we propose to determine the index of each indicator in this calculation so that they can be compared regardless of the units of measurement. The competitiveness index is defined as the ratio of the value of the respective indicator to its highest value among the entire set of indicators of enterprises.

For example, Table 1 shows how the indices for assessing the financial condition of enterprises in 2023 were calculated.

Table 1. Assessment of the financial condition of enterprises, 2023

№	category of enterprises according to KVED	wear factor		coefficient of autonomy		solvency ratio		capital turnover ratio		coefficient of return on capital	
		-	index	-	index	-	index	-	index	-	index
1	Group 1	**0,48**	0,69	**0,31**	0,82	**4,38**	1,00	**1,03**	0,52	**0,08**	0,47
2	Group 2	**0,54**	0,78	**0,36**	0,95	**1,54**	0,35	**0,97**	0,49	**0,10**	0,59
3	Group 3	**0,57**	0,83	**0,37**	0,97	**1,53**	0,34	**1,20**	0,61	**0,14**	0,82
4	Group 4	**0,69**	1,00	**0,38**	1,00	**3,28**	0,75	**1,98**	1,00	**0,17**	1,00
5	Group 5	**0,45**	0,65	**0,29**	0,76	**1,51**	0,34	**1,26**	0,64	**0,10**	0,59

Table 2 reveals how the indices for assessing the efficiency of enterprises' production in 2023 were calculated.

Table 2. Assessment of the production efficiency of enterprises, 2023

№	category of enterprises according to KVED	complex indicator	index
1	Group 1	0,89	0,41
2	Group 2	0,90	0,42
3	Group 3	1,23	0,57
4	Group 4	2,15	1,00
5	Group 5	0,92	0,43

Table 3 displays how the indices for assessing the efficiency of enterprise product sales in 2023 were calculated.

Table 3. Assessment of the efficiency of sales of enterprises' products, 2023

№	category of enterprises according to KVED	return on the sales ratio	index	selling expenses profitability ratio	index
1	Group 1	0,23	0,77	11,15	0,03
2	Group 2	0,30	1,00	354,49	1,00
3	Group 3	0,24	0,80	41,32	0,12
4	Group 4	0,23	0,77	24,66	0,07
5	Group 5	0,27	0,90	58,93	0,17

The calculation of the indices for assessing the social performance of enterprises in 2023 is shown in Table 4.

Table 4. Assessment of social performance of enterprises, 2023

№	category of enterprises according to KVED	Share of unified social contribution in net income	index	average salary growth rate	index
1	Group 1	0,05	1,00	1,73	1,00
2	Group 2	0,03	0,60	1,33	0,77
3	Group 3	0,04	0,80	1,38	0,80
4	Group 4	0,01	0,20	1,53	0,88
5	Group 5	0,04	0,80	1,63	0,94

The calculation of the indices for assessing the image of enterprises in 2023 is presented in Table 5.

Table 5. Assessment of the Image of enterprises, 2023

№	category of enterprises according to KVED	net income growth rate	index
1	Group 1	2,97	0,83
2	Group 2	1,73	0,48
3	Group 3	1,67	0,47
4	Group 4	2,11	0,60
5	Group 5	3,58	1,00

Table 6 shows the indices for assessing enterprises' labour activity efficiency in 2023.

Table 6. Assessment of labour efficiency of enterprises, 2023

№	category of enterprises according to KVED	labour efficiency	index
1	Group 1	3,93	0,08
2	Group 2	19,04	0,42
3	Group 3	5,60	0,12
4	Group 4	29,99	0,67
5	Group 5	44,78	1,00

4. Research results

4.1 Calculation of competitiveness levels of machine-building enterprises

Based on the calculations, tables of indices of competitiveness criteria of individual groups of machine-building enterprises for the entire study period were formed. Table 7 shows the values for 2023.

Table 7. Indices of competitiveness criteria of enterprises

№	category of enterprises according to KVED	production efficiency	financial position	product efficiency	social efficiency	image	labour activity
1	Group 1	0,41	3,50	0,80	2,00	0,83	0,08
2	Group 2	0,42	3,16	2,00	1,37	0,48	0,42
3	Group 3	0,57	3,57	0,92	1,60	0,47	0,12
4	Group 4	1,00	4,75	0,84	1,08	0,60	0,67
5	Group 5	0,43	2,98	1,07	2,82	1,00	1,00

These data enable an improved methodology for determining companies' overall competitiveness and calculating it for the entire study period by category. The results are presented in Table 8.

Table 8. Integral indicator of competitiveness

№	category of enterprises according to KVED	**Years**			
		2020	**2021**	**2022**	**2023**
1	Group 1	0,08685	0,08464	0,06153	0,08769
2	Group 2	0,10821	0,10916	0,09173	0,10671
3	Group 3	0,09872	0,10720	0,07811	0,08883
4	Group 4	0,10366	0,11592	0,08993	0,11882
5	Group 5	0,11101	0,09551	0,12256	0,13137

Thus, Group 5 enterprises exhibited the highest competitiveness in 2020, 2022, and 2023, while Group 4 enterprises demonstrated the highest competitiveness in 2021. Thus, enterprises with KVED 30. "Manufacture of other vehicles" should receive the most state support, especially those producing products for the country's military and defence sector.

4.2 Economic and Mathematical Modelling of Forecast Indicators of Competitiveness of Enterprises in the Machine-Building Industry

The next stage of the study is modelling the forecast indicators of the short-term competitiveness of the researched enterprises. For this purpose, economic and mathematical models with different functions were built for each group of enterprises: linear, exponential, logarithmic, polynomial of the 2nd degree, and power law. For all groups of enterprises, the

highest correlation coefficient is observed when using the polynomial approximation model, as shown in Figures 1-5.

Such a low probability of calculating the forecast values is because two pre-war (2020 and 2021) and two war years (2022 and 2023) were used for the study. This fact also determined the illogical results of machine-building enterprises' financial, economic and business activities: a sharp decline in the integrated competitiveness indicator in 2022 for the first four groups of enterprises.

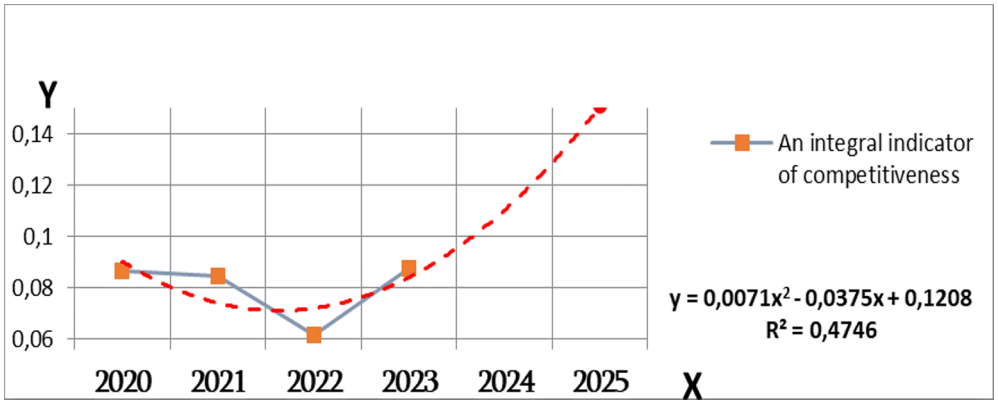


Fig. 1. Polynomial approximation model for Group 1 enterprises

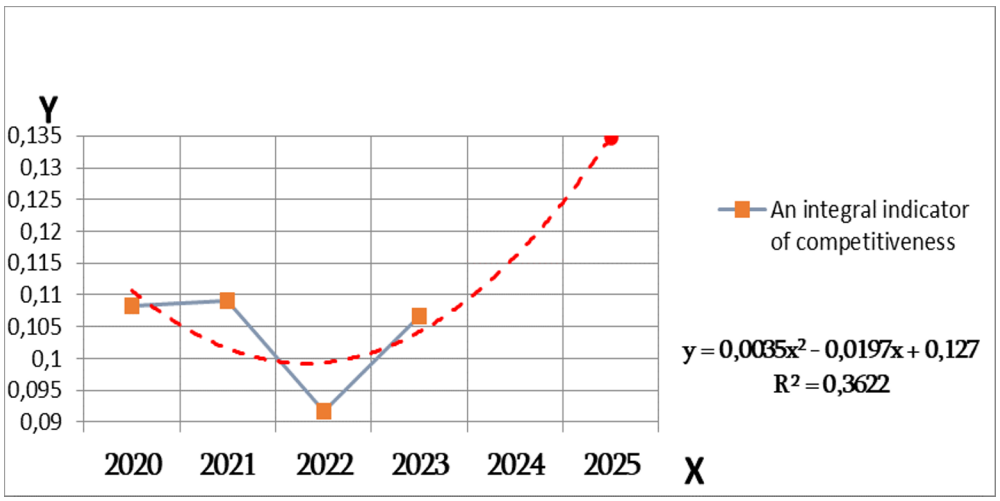


Fig. 2. Polynomial approximation model for Group 2 enterprises

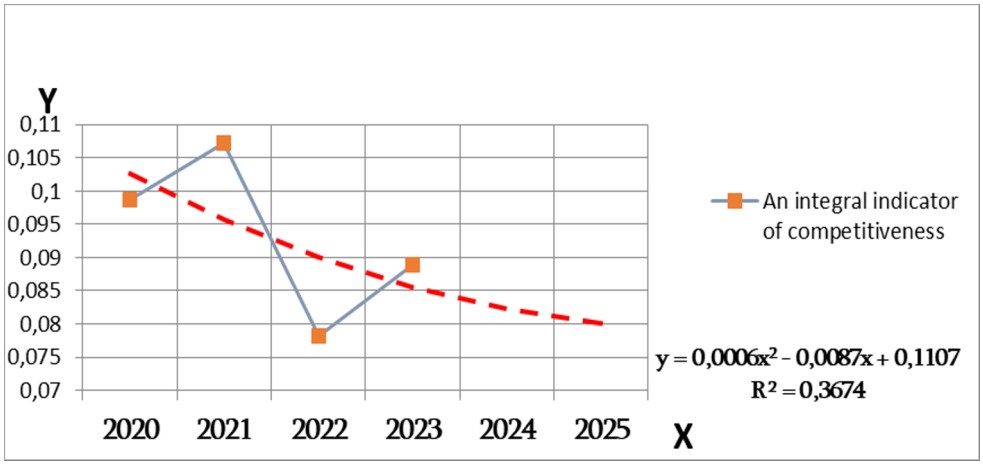


Fig. 3. Polynomial approximation model for Group 3 enterprises

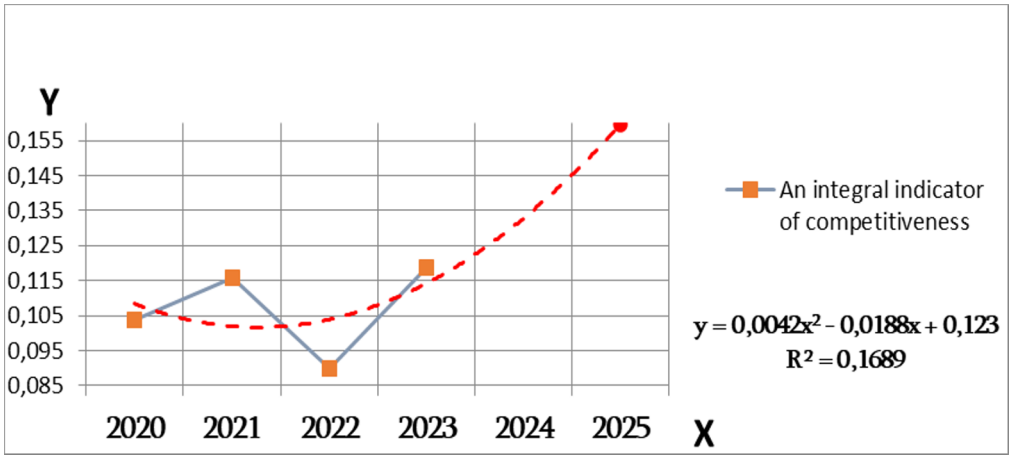


Fig. 4. Polynomial approximation model for Group 4 enterprises

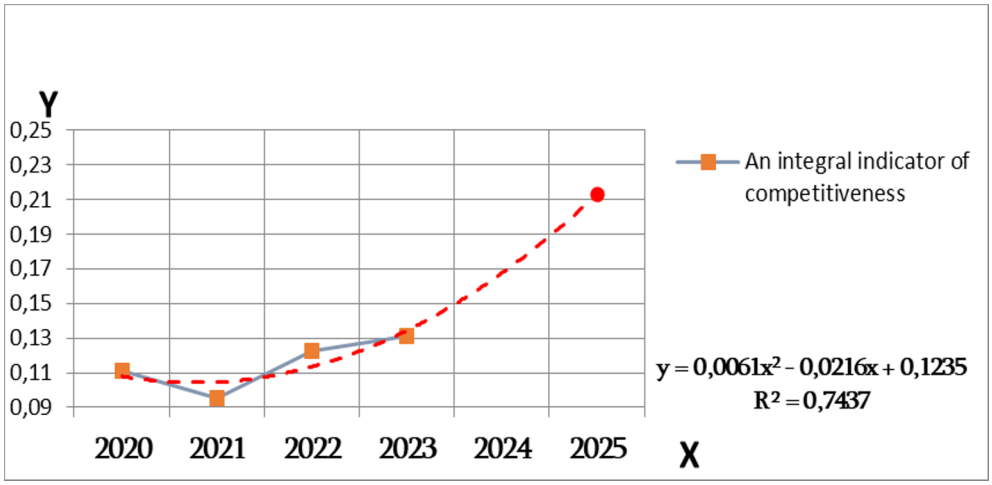


Fig. 5. Polynomial approximation model for Group 5 enterprises

Based on the calculations, it is possible to predict with a high degree of confidence (for 2025) the value of the integrated competitiveness indicator for enterprises of Group 5 at 0.2135, which indicates their potential development in the short term. The machine-building enterprises of this group require exceptional state support in the form of targeted programmes, interest-free loans, tax benefits, and employee reservations.

5 Conclusion

Given all of the above, the competitiveness of machine-building enterprises should be calculated in terms of individual categories (groups), which are determined by the existing classifier of Ukrainian economic activities. An intra-sectoral methodological approach to assessing the competitiveness of machine-building enterprises is proposed and substantiated. A study of the financial statements of 38 economic entities in the industry identified for the respective group of enterprises was carried out based on the five groups.

In contrast to the methodology of integral assessment of the competitiveness of industrial enterprises, substantiated by Oberemchuk, the following list of criteria and relevant indicators for assessing the intra-sectoral competitiveness of machine-building enterprises is proposed:

- The criterion for the efficiency of the company's production activities: a comprehensive indicator that includes net income from sales of products, labour costs, working capital, and fixed assets;
- the criterion that characterises the financial condition of the company: depreciation, solvency, autonomy, return on equity and capital turnover ratios;
- labour efficiency criterion is a comprehensive indicator that includes labour productivity and labour costs;
- the criterion that reflects the efficiency of the sales organisation: the ratio of profitability of sales costs and profitability of sales;
- the criterion of product competitiveness is not significant for machine-building enterprises since enterprises produce original (non-competitive in the domestic market) products within a specific group and, therefore, is taken as a unit for all categories;
- social efficiency criterion: average salary growth rate, share of unified social tax in total net sales revenue;
- the criterion of environmental friendliness of production is not significant for machine-building enterprises since they do not pay environmental tax, and therefore is taken as one for all categories;
- image criterion: net sales revenue growth rate.

It is essential to note that the indicators used in the above calculations cannot be consolidated into one criterion. Therefore, the index of each indicator should be determined so that they can be compared, regardless of the units of measurement. Based on the calculations, tables of indices of competitiveness criteria for individual groups of enterprises of the machine-building complex for 2020-2023 have been formed.

The calculations allowed us to determine the integral indicators of the competitiveness of enterprises for the entire period of the study and to form their rating. As a result of the calculations, the highest indicator is observed for enterprises in Group 5 in 2020, 2022 and 2023. In 2021, the highest level of competitiveness was determined for Group 4 enterprises. Thus, enterprises with KVED 30. "Manufacture of other vehicles" should receive the most state support, especially for those producing products for the country's military and defence sector.

Based on economic and mathematical modelling, the forecasted values of the integral competitiveness indicators show that only enterprises in the 5th group can be predicted with high confidence, highlighting their potential for short-term growth. The machine-building

enterprises of this group require exceptional state support in the form of targeted programmes, interest-free loans, tax benefits, and employee reservations.

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