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ANALYSIS AND MODELING OF AN IRON ORE ENTERPRISE'S PRODUCTION POTENTIAL IN KRYVYI RIH REGION

Purpose. To determine specific aspects of the influence of components of ore mining enterprises' production potential (evidence from the PJSC "Kryvyi Rih Iron Ore Works") on financial efficiency of their activities and to establish a successful management strategy under local and global competitive conditions considering impacts of technological trends.

Methodology. Modeling and comparative analysis of econometric models of production potential development with and without considering scientific and technological progress factors, applying best practices of forecasting an enterprise's financial results.

Findings. Additive and multiplicative models of influence of key components of production potential on the enterprise's financial activity results in Kryvyi Rih region are developed, and efficiency of these models is analyzed. Special attention is paid to scientific and technological progress impacts on efficiency of the enterprise's activities, and specificity of the impact is considered when developing the program of strategic development of the enterprise.

Originality. The econometric modeling apparatus is applied for the first time to study impacts of production potential factors on efficiency of financial activities of a Kryvyi Rih region enterprise considering scientific and technological progress factors. The results are subject to detailed economic-mathematical analysis and the built models are used for forecasting.

Practical value. The results obtained during the study are of practical value for managing large iron ore enterprises and can be used by them when developing strategic plans of managing their financial and operational activities.

Keywords: *iron ore industry, industrial enterprise, production potential, scientific and technological progress, econometric modeling, forecasting of financial results*

Introduction. As is known, production potential, its structure and complete use of all its components, namely natural and climatic factors, fixed and current capital, intangible and tangible assets, are an integral and determinative component of an industrial enterprise's financial efficiency [1]. It is production potential that determines efficiency of management in distribution, planning and analysis of all the enterprise's resources, what market niche the enterprise fills or will fill considering impacts of the competitive environment. Here, current trends of technology development, i.e. the scientific and technological progress factor, produce a significant impact on dynamics of production process components. These processes, their interaction, specificity of structural relations between these components can be investigated by means of econometric methods for modeling complex financial-economic processes. Therefore, studying optimization of the production potential structure based on current approaches and methods of economic and mathematical modeling is an important and topical issue for national industrial enterprises.

Literature review. Theoretical and practical aspects of the structure, specificity of forming and using production potential components are dealt with in works by B. Ryan, R. Grant, E. Mansfield, B. Szántó, D. Collis, B. Twiss and others. Various aspects of production potential formation and functioning are studied by national researchers among which the works by Maksimova O. S., Maksimova S. V., [1], Grabchuk O. M., Plaksienko V. Ya. [2], Lapina I. S., Dombrovskaya S. O. [3], Gayevskaya L. M. [4], Kostirko R. O. [5], P. G. Break, Kobeleva T. A., Tkachova N. P. [6], Beetle O. E. [7], Shkromidi N. Ya. [8], Ahaman I. A. [9] and others. Special features of modeling production potential as a sphere of an enterprise functioning are presented by the production function covered in detail in the writings of such domestic scientists as Karachina N. P. [11], Yankovsky O. G. [12], Donchenko V. S., Nazaraga I. M. [13], Skiba G. V. [15], Vakaruk T. S. [16], Bobko L. O. [17], and others.

Unsolved aspects of the problem. The issue of using the production function apparatus for iron ore enterprises specially is not sufficiently covered and requires further investigation. National researchers do not pay sufficient attention to analyzing scientific and technological progress (STP) influencing the mechanism of interaction of production potential components and financial results of iron ore enterprises' activities. Therefore, these problems are subject to thorough analysis and improvement.

Purpose. The main objective of the study is investigating, modeling, comparing and forecasting specificity of production potential of an iron ore enterprise of Kryvyi Rih region (evidence from the PJSC "Krivorizkyi zalizorudnyi kombinat" (PJSC KZRK)) considering the specific factor of scientific and technological progress, investigating impacts of these components on financial results of the enterprise performance and using the built models for forecasting net income of the enterprise for future periods of its functioning.

Methods. Methods for determining production potential are directly connected with such economic categories as "production function" and "production capacity" [2]. Therefore, priority is given to formation and estimation of an enterprise's production function and capacity. The production function is known to mean that a certain quantity of goods can be produced within a work period with a certain combination of equipment, labor and other factors [4]. To control efficiency of production potential, make sound decisions on its prospective change, it is necessary to be able to make quantitative measurements of these connections. This economic problem can be solved through building an econometric model [9]. Results of the studies show that such analytical forms of functions as linear (additive) and power (multiplicative) ones are the most relevant for building an econometric model of an industrial enterprise's production potential efficiency.

At that, a power function is realized as a linear one if input data for building a model are not in absolute units but in logarithms [10].

Production potential differs from production capacity in the fact that the latter is the greatest possible outputs within a certain time period with common use of resources; but production potential is the greatest possible outputs within a certain time period with optimal use of resources, in conditions of scientific and technological progress [12]. To sum up impacts of all qualitative changes on production, the technological progress indicator is the function of time. At that, technological progress is meant as a wide range of phenomena: the scope of quantitative changes of economic growth factors as distinct to their purely quantitative growth [14]. Scientific and technological progress is an integral component of the national economy. It enables its development under limited resources and establishment of pre-requisites of positive shifts under world financial crises. The qualitative evaluation of using STP in the national economy enables detecting bottlenecks in its development and establishing the efficient strategy of the national development [15].

To produce more qualitative forecasts, the Cobb-Douglas-Tinbergen production function is applied that looks as follows [13]

$$Y = \hat{a}_0 \cdot L^{a_1} \cdot K^{a_2} \cdot e^{a_3 \cdot t}, \qquad (1)$$

where t is a time variable in the production function; L is a factor characterizing labor resources; K is a factor characterizing capital resources; $\hat{a}_0,\ \hat{a}_1,\ \hat{a}_2,\ \hat{a}_3$ are unknown model parameters.

After building and validating the model, it is reasonable to analyze the economic essence of the model parameters.

The average factor efficiency indicator is one of the principal economic characteristics of the model of production potential efficiency. The indicator determines average changes in labor efficiency if the jth factor is changed by one and the rest $j - 1$ are constant [16].

The marginal efficiency indicator is another important economic characteristic. It describes the marginal change in production potential regardless of the change in a certain factor by one providing the other factors do not change [16].

Another important characteristic, relative marginal efficiency of factors or the elasticity ratio, shows how much efficiency of production potential will change depending on the corresponding factor change by 1 % (the other factors stay unchanged) [17].

The model of production potential efficiency enables various combinations of factor values that ensure the pre-set (fixed) level of production. For this, it is required to solve the equations of production potential efficiency with respect to one of the factors which is considered a dependent variable. The equations are analytical expression of the isoquant of production potential efficiency [15].

If certain production volumes can be achieved at various combinations of factors, they can be treated as interchangeable ones in relation to a certain level of production potential efficiency and relative rates of factor substitution can be built. The marginal substitution rate shows by what quantity the factor X_j should be increased, along with X_k decreased by one, to keep production volumes unchanged [9].

The econometric model of production potential efficiency enables analysis of production activities and determines ways of its improvement to enhance efficiency. Validity of the analysis depends totally on reliability of the econometric model, the degree of its adequacy to the real process [10].

The authors have built and analyzed models of efficient use of production potential of the PJSC KZRK and studied how the scientific and technological progress factor impacts production efficiency of the enterprise. The data for determining variables in the model were obtained from financial records of the enterprise (Form 1 "Balance" and Form 2 "Profit and Loss Statement").

Output is a key accounting unit at manufacturing enterprises. Information on outputs is revealed in Form 2 "Profit and Loss Statement". According to Accounting Principles (Standards) 3 "Profit and Loss Statement", manufacturing and sales of products belong to basic activities of an enterprise. The article "Product (Goods, Work, Service) Sales Income" presents the total income from sales of its products without discounts, insurance indemnity, return of merchandise and indirect taxes (VAT, excise duties and others) [13]. Therefore, to identify the dependent variable Y, the following data are used in the model

Y = form 2 line 2000 "Net Product (Goods, Work, Service) Sales Income".

The data for modelling components of production potential of the enterprise are obtained on the basis of its financial records in the following way.

Land potential and intangible assets potential are determined as follows

X_1 = *f. 1 (l. 1000 "Intangible Assets" + l. 1005 "Uncompleted Capital Investments".*

Fixed assets potential is determined as follows

X_2 = *f. 1 l. 1010 "Fixed Assets".*

Current capital potential is determined as follows

X_3 = *f. 1 (l. 1101 "Inventories" + l. 1102 "WIP Inventories" + + l. 1170 "Deferred Costs").*

Personnel potential is determined as follows

X_4 = *f. 2 l. 2505 "Labor Costs".*

These indicators are independent factors of the model.

Results. Thus, modeling aims at building analytical functions of influence of five factors on production (net sales income) of the enterprise. Input data for building the model are given in Table 1.

The initial stage of modeling comprises specification of the model that looks like the following

$$Y = f(X_1, X_2, X_3, X_4, u).$$

In this econometric model, u is a stochastic component that considers impacts of arbitrary factors on the net income level of the enterprise.

Table 1

Input data for modeling the relationship between net income and components of the production capacity of PJSC "KZRK" (thousand UAH) [18]

Year	Net income from the product sales (a dependent factor)	Land and intangible assets potential (X_1)	Fixed assets potential (X_2)	Current capital potential (X_3)	Technological personnel potential (X_4)
2007	876 951	106 947	665 896	42 567	229 334
2008	1 022 146	152 886	645 323	50 850	229 425
2009	1 968 180	225 374	656 045	44 645	267 696
2010	1 126 579	230 382	647 483	42 827	276 440
2011	2 869 648	276 694	707 645	61 388	375 612
2012	4002038	343 492	786 479	81 494	431 882
2013	3 057 548	301	2 069 990	58 613	491 494
2014	3 035 186	1905	2 267 688	84 012	487 305
2015	3 691 909	2218	2 417 181	106 423	598 838
2016	2 948 788	2089	2 576 503	147 241	706 022
2017	4 453 106	2011	2 689 497	113 119	757 481
2018	5 436 220	2245	2 913 735	178 284	932 637

Analytically, the function is given in the following forms:

1) linear

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + u;$$

2) power (without STP)

$$Y = a_0 X_1^{a_1} X_2^{a_2} X_3^{a_3} X_4^{a_4} u;$$

3) power (with STP)

$$Y = \hat{a}_0 \cdot X_1^{\hat{a}_1} \cdot X_2^{\hat{a}_2} \cdot X_3^{\hat{a}_3} \cdot X_4^{\hat{a}_4} \cdot e^{\hat{a}_5 \cdot t} \cdot u,$$

where $\hat{a}_j$ is measurements of the jth parameter of the model ($j = 0, 1, 2, 3, 4, 5$); $e^{\hat{a}_5 \cdot t}$ is the time variable in the function of the enterprise's production potential efficiency.

Correspondingly, the sample frame of calculated functions is as follows:

1. $Y = \hat{a}_0 + \hat{a}_1X_1 + \hat{a}_2X_2 + \hat{a}_3X_3 + \hat{a}_4X_4$.
2. $Y = \hat{a}_0 X_1^{\hat{a}_1} X_2^{\hat{a}_2} X_3^{\hat{a}_3} X_4^{\hat{a}_4}$.
3. $Y = \hat{a}_0 \cdot X_1^{\hat{a}_1} \cdot X_2^{\hat{a}_2} \cdot X_3^{\hat{a}_3} \cdot X_4^{\hat{a}_4} \cdot e^{\hat{a}_5 \cdot t}$.

It should be noted that power functions are realized as linear-logarithmic ones.

Based on 12 observations (n = 12), applying the least-squares method 1 LSM, econometric functions are built for linear and power functions. To perform regression analysis, Data Analysis Add-in and the Regression tool in Excel were used. Let us give closer consideration to calculation results that provide the greatest number of characteristics of variables interconnections.

Table 2 presents basic indicators of regression statistics obtained for linear and power models of production potential efficiency of the enterprise under study.

According to the built models, there is quite a tight connection between the net income and the components of the enterprise's production potential. The values of "R-squared" testify to strong conformity of the regressive models with the input data. As the calculated values of R-squared are greater than 85 %, it can be concluded that these models may be used for forecasting. Normalized R^2 values differ from R^2 by only 0.05, so it is possible to say that R^2 is a highly reliable coefficient.

Let us calculate the relation of the standard error to average values of the variable Y as percentage:

- for the linear model, %

$$S_u / Y_{aver} = 511\,811.3122/2\,874\,024.917 = 17.81;$$

- for the power model without STP impacts (in the linear-logarithmic form), %

$$S_u / Y_{aver} = 0.274861463/14.72634371 = 1.87;$$

- for the power model with STP impacts (in the linear-logarithmic form), %

$$S_u / Y_{aver} = 0.286293885/14.72634371 = 1.94.$$

A model is considered better when a standard error is less than 30 %.

Thus, the detailed analysis of basic indicators of model adequacy indicates that the model that considers STP impacts possesses higher coefficient values and is more reliable.

To obtain a regression equation, it is necessary to determine characteristics of precision of the regression equation that is the relation of that part of the dependent variable variance explained by the regression equation to the unexplained (residual) part of variance. Table 3 presents the results of the calculations.

When analyzing the data in Table 3, we should note that the residual sum of squares of deviations from the average value of the resultant criterion is less than 30 %. So, regression equations approximate closely a set of input observations. Sampled regressive and residual variances characterize slight

Table 2

Indicators of regression statistics of models of influence of production potential on the efficiency of production of PJSC "KZRK"

The name of the coefficient	The values of the coefficients		
	Linear model	Power model without consideration of STP factor	Power model considering the STP factor
Multiple R	0.958113935	0.931977255	0.936904618
R-square	0.917982312	0.868581604	0.877790264
Normalized R-square	0.871115062	0.793485378	0.775948817
Standard error	511 811.3122	0.274861463	0.286293885
Observation	12	12	12

deviations of theoretical indicators from actual ones and thus testify to reliability of the built models. The *F*-criterion value, $F_{fact} > F_{table}$ i.e. the connection significance hypothesis, is accepted and the models are statistically significant. In conformity with the calculated levels of *F*-criteria significance, it is possible to conclude that regression equations (dependence) are significant with probability of 95 %. At that, it should be noted that most indicators in the Table are better for the model considering the STP factor. This, again, characterizes its greater practical relevance and applicability to forecasting.

The next stage in regression analysis of dependence of the PJSC "KZRK" net income on production potential factors is study of ratios for regressors. The calculation results are given tin Table 4.

According to the obtained ratios given in Table 4, econometric models of efficient use of production potential of the PJSC "KZRK" will look as follows:

- in the linear form

$$\hat{Y} = -1\,982\,957.3 + 8.6015\overline{X}_1 + 1.1917\overline{X}_2 - 16.392\overline{X}_3 + 7.0167\overline{X}_4;$$

- in the power form without the STP factor

$$\hat{Y} = 0.00273 \cdot \overline{X}_1^{0.073918} \cdot \overline{X}_2^{-0.097957} \cdot \overline{X}_3^{-0.734526} \cdot \overline{X}_4^{2.274816};$$

- in the power form with the STP factor

$$Y = (2.2105E-12) \cdot X_1^{0.1916} \cdot X_2^{0.6495} \cdot X_3^{-1.0474} \cdot X_4^{3.3422} \cdot e^{-0.1667 \cdot t}.$$

Column 3 of Table 4 contains standard errors of model parameters evaluations. Pairwise comparison of values from columns "Ratios" and "Standard errors" shows that not all absolute values of the ratios are greater than the standard error values. This may testify to significance of regressors; however, this analysis is rough.

Column 4 "t-criteria" of Table 4 contains more precise evaluation of ratio significance. The column presents Student's t-criteria. The table value of the t-criterion is 2.365 at

Table 3

The results of the analysis of variance

Indexes	df	SS	MS	F	Significance F
Linear model					
Regression	4	2.05232E + 13	5.13079E + 12	19.58686101	0.000665674
Remainder	7	1.83366E + 12	2.61951E + 11	–	–
Total	11	2.23568E + 13	–	–	–
Power model without consideration of STP factor					
Regression	4	3.495265856	0.873816464	11.56624839	0.003324159
Remainder	7	0.528841768	0.075548824	–	–
Total	11	4.024107624	–	–	–
Power model considering the STP factor					
Regression	5	3.532322493	0.706464499	8.619184927	0.010372214
Remainder	6	0.491785131	0.081964189	–	–
Total	11	4.024107624	–	–	–

Table 4

The results of calculating model parameter estimates and their significance

	Values	Standard error	t-statistics	P-value
Linear model				
Y-section	–1982957.359	895062.861	–2.215439211	0.062295144
Variable X_1	8.601569298	3.783151691	2.273651706	0.057168843
Variable X_2	1.19175705	1.011564263	1.178132812	0.277238467
Variable X_3	–16.39200842	11.88413144	–1.37931901	0.210250313
Variable X_4	7.016763025	4.06794447	1.724891546	0.128200503
Power model without consideration of STP factor				
Y-section	–5.90266298	10.34942189	–0.570337458	0.586281019
Variable X_1	0.073917896	0.192870609	0.383251219	0.712906883
Variable X_2	–0.097957968	1.133010205	–0.086458152	0.933523335
Variable X_3	–0.73452637	0.724381896	–1.014004317	0.344340023
Variable X_4	2.274815607	0.718279545	3.167033815	0.015772898
Power model considering the STP factor				
Y-section	–26.83778472	32.9487428	–0.814531373	0.44645679
Variable X_1	0.191688401	0.266526158	0.719210462	0.499052491
Variable X_2	0.649508027	1.621265078	0.400618033	0.702576838
Variable X_3	–1.047442192	0.886490202	–1.181560936	0.282084587
Variable X_4	3.342263693	1.75500226	1.904421304	0.105520975
Variable X_5	–0.166784959	0.248048128	–0.672389509	0.526367317

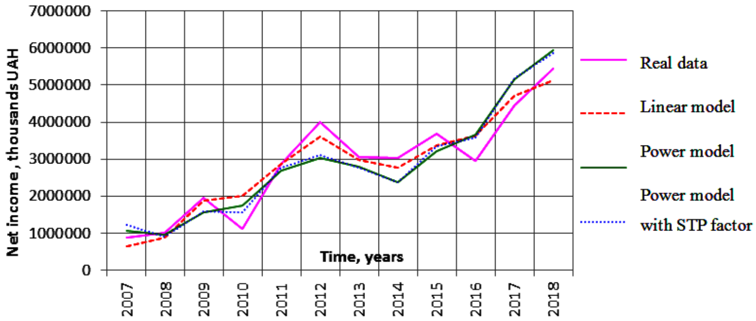

Fig. 1. Diagrams of models of PJSC "KZRK" production potential

$\alpha = 0.05$ and $n - m - 1 = 7$. Reliability of an econometric model can only be achieved at the expense of individual parameters; the other parameters may be unreliable. So, it is reasonable to assess significance of each parameter of models comparing tact with ttable. According to this criterion, all the parameters of the linear model are insignificant. For a power model, only the $\hat{a}_4$ parameter is reliable.

Column 5 "Significance level" of Table 4: p-value is probability of the fact that the critical value of the used criterion statistics (Student's statistics) will exceed the calculated sampled one. In this case, *p*-value is compared with the chosen significance level (0.05). If significance level is less than 0.05, then with probability of 0.95 it is arguable that the evaluated parameters are reliable. This may enable the conclusion that the parameters $\hat{a}_0$ and $\hat{a}_1$ of the linear model may be considered reliable; the parameter $\hat{a}_4$ is reliable for the power model.

Thus, the data from Table 4 indicate that parameters according to the Student criteria in the built models are insignificant. This is explained by negative dynamics of most factors, while the value of the enterprise's net income tends to increase. Besides, the parameter a_0 is of no significance in the models, indicating the low level of production reserves and dependence of net income on production potential components.

Besides, it should be noted that analysis of the power model of efficiency of production potential considering STP impacts indicates that the value of the parameter characterizing STP development is negative ($a_5 = -0.166785$). In the mathematical sense, it indicates the negative impact of STP on the enterprise's production, yet from the economic point of view, this idea lacks any sense. Parallel analysis of two power models reveals that the negative value of the parameter in the second model reflects a multiplicative effect between STP and other components of production potential. This effect enables concluding that STP growth rates are lower than those of other factors of production potential, i.e. application of STP achievements in the enterprise's activity is decreasing in time.

Therefore, in accordance with the calculated characteristics (ratios of determination, correlation, Student-Fisher criteria) applied to evaluating adequacy of the models, we can conclude that the built functions reflect close interrelation between the amount of net income and factors impacting production potential of an industrial enterprise.

The resulted models are graphically presented and compared with dynamics of actual values of net income from sales at the PJSC "KZRK" (Fig. 1).

As is seen from Fig. 1, all the models in dynamics reveal significant approximation to actual data, while the power models considering and without considering STP factors are more sensitive to fluctuations of actual values of the analyzed factor.

After building the model of efficiency of production potential use and proving adequacy of these models parameters, we fulfill economic and mathematical analysis of the models and analyze the influence of individual factors on the net income of the enterprise. To perform this, we calculate the following economic characteristics:

1. Average efficiency of the factors impacting labor efficiency calculated by the formula

$$\Pi_j = \frac{\bar{\hat{Y}}}{\bar{X}_j},$$

where $j = 1, 2, 3, 4, 5$.

Table 6 gives the results of calculating average efficiency for the built models.

After analyzing the data from Table 5, we can conclude that with changing the amount of intangible assets by 1 UAH, the enterprise net income changes by 25.61 UAH on average providing the other factors remain unchanged. In a similar way, increased fixed assets increase the enterprise's net income by 1.81 UAH, providing the rest of the factors remain unchanged. Also, through changing current assets by one, the enterprise net income changes by 34 UAH on average, providing the other factors are unchanged. Concerning the factor of technological personnel potential, its change by one will provoke the change of net income by 5.92 UAH.

As to the STP factor influencing the enterprise's industrial processes, it should be kept in mind that it is expressed through the exponential function and characterizes general time changes in net income under the influence of objective changes of technological development of industrial processes in economy. The value of average efficiency of changed net income under the STP influence indicates the increase in average production efficiency by 133.04 UAH in the period under study annually. This factor can also incarnate general economic processes occurring in both economy and the enterprise's activity without considering production factors.

Table 5

The value of the average efficiency of the impact of factors of production potential for the net income of PJSC "KZRK" (Table 1)

Indicator	Linear model	Power model without consideration of STP factor	Power model considering the STP factor
Land and Intangible Assets (X_1)	25.61245604	25.42306	25.43930245
Fixed assets potential (X_2)	1.811030661	1.797638	1.798787147
Current Funds Potential (X_3)	34.09744004	33.84529	33.86692353
Technological staff potential (X_4)	5.962536172	5.918444	5.922226312
Potential of scientific and technological progress (X_5)	–	–	133.0437718

2. Marginal efficiency of changes in production volumes in case of changing each production potential factor by one.

Marginal efficiency of factors in the linear model is characterized by its parameters

$$\frac{\partial \hat{Y}}{\partial X_j} = \hat{a}_j..(j = 1,2,3,4).$$

For the power model of efficiency of production potential use, this factor will depend on x_j values and is calculated by the formula

$$\frac{\partial \hat{Y}}{\partial x_j} = a_j \frac{\hat{Y}}{x_j}(j = 1,2,3,4).$$

It is worth noting that for the power model with STP, the number of independent factors equals 5, while the value of marginal efficiency for the STP factor influencing the enterprise's net income will be determined by the following formula

$$\frac{\partial \hat{Y}}{\partial x_5} = a_5 \cdot \hat{Y}.$$

In other words, we obtain the value of marginal efficiency for power functions through model parameters and corresponding values of average efficiency. Table 6 presents the results of calculating marginal efficiency of the built models factors.

Marginal efficiency of the enterprise's industrial processes influenced by the production potential factors changes as follows.

For the linear model:

- the increased potential of land and intangible assets by one unit will cause marginal increase in net income by 8.601 units providing the other factors remain stable;

- if the amount of fixed assets potential is increased by one, marginal net income will increase by 1.19 units providing the other factors remain stable;

- increase in current assets potential will cause marginal decrease in net income by 16.39 units providing the other factors of production potential remain stable;

- the size of technological personnel increased by one will cause increased marginal production potential by 7.016 units under stable amounts of other production factors.

For the power model:

- increase in land and intangible assets potential by one will cause marginal increase in net income by 1.87 units providing the remaining factors are stable;

Table 6

Values of marginal efficiency of production potential factors influencing net income of the PJSC "KZRK" (Table 1)

Indicator	Linear model	Power model without consideration of STP factor	Power model considering the STP factor
Land and Intangible Assets (X_1))	8.601569298	1.879219	4.87641922
Fixed assets potential (X_2)	1.19175705	–0.17609	1.168326691
Current Funds Potential (X_3)	–16.39200842	–24.8603	–35.4736446
Technological staff potential (X_4)	7.016763025	13.46337	19.79364198
Potential of scientific and technological progress (X_5)	–	–	–476103.512

- if the amount of fixed assets potential is increased by one, this will cause marginal decrease in net income by 0.17 units considering stability of other factors;

- increase in current capital potential will cause marginal decrease in net income by 24.86 units under stability of other factors of production potential;

- increase in the number of technological personnel by one will cause increase in marginal production efficiency by 13.46 units under constant amounts of other production factors.

For the power model considering the STP influence:

- increase in the land and intangible assets potential by one will cause marginal increase in net income by 4.87 units proving the other factors are stable;

- if the amount of fixed assets potential is increased by one, marginal net income will be increased by 1.16 units considering stability of other factors;

- increase in potential of current capital will cause marginal decrease in net income by 35.47 units providing stability of other factors of production potential;

- increase in the number of technological personnel by one will cause increase in marginal production efficiency by 19.79 units under constant amounts of other production factors;

- marginal decrease in production under stability of all the production potential factors and changes in external conditions of industrial and technological processes in the economy in the analyzed period makes 476 103 dollar equivalents, that revealing the necessity of considering technological refit to maintain positive production rates and increased production efficiency.

Comparing marginal efficiency of factors in the linear and power models, one can notice that they differ in terms of quantity and change trends, the latter concerning the factor of fixed assets potential. In the power model, increase in fixed assets use can provoke decreased production volumes. Yet, in the model considering STP impacts, the positive value of this factor is compensated by negative changes of STP impacts. This can indicate an obsolete character of the enterprise's fixed assets accompanied by other factors. In other words, the multiplicative law of forming production potential efficiency is more applicable than the additive one.

3. Elasticity ratios of production potential.

$$E_{Y/X_j} = a_j : \frac{\bar{\hat{Y}}}{\bar{X}_j}.$$

For the power model, elasticity ratios are stable and equal the model parameters. Indeed,

$$E_{Y/X_1} = \frac{\partial \hat{Y}}{\partial X_1} : \frac{\hat{Y}}{X_1} = \frac{\hat{a}_0 \hat{a}_1 X_1^{\hat{a}_1 - 1} X_2^{\hat{a}_2} X_3^{\hat{a}_3} X_4^{\hat{a}_4} X_1}{\hat{a}_0 X_1^{\hat{a}_1} X_2^{\hat{a}_2} X_3^{\hat{a}_3} X_4^{\hat{a}_4} X_1} = a_1.$$

For the STP factor within the power model, elasticity will be calculated as follows

$$E_{Y/X_5} = \frac{\partial \hat{Y}}{\partial X_5} : \frac{\hat{Y}}{X_5} = \frac{a_5 \cdot \hat{Y} \cdot X_5}{\hat{Y}} = a_5 \cdot e^{a_5 \cdot t} = -0.1667 \cdot e^{-0.1667 \cdot t}.$$

Unlike elasticity indicators for other components of production potential, the elasticity indicator for STP is a changeable characteristic depending on time and indicates the economic essence of STP expressed by its ongoing growth.

Table 7 reveals elasticity ratios of production potential factors for the built models.

The calculated elasticity ratios for the linear model reveal the following:

- if potential of land and intangible assets is increased by 1 %, the enterprise's net income increases by 0.3358 % providing the other factors are stable;

- if potential of fixed assets is increased by 1 %, the enterprise's net income increases by 0.658 % providing the other factors are unchanged;

Table 7

Values of elasticity ratios of production potential factors of the PJSC "KZRK" (Table 1)

Indicator	Linear model	Power model without consideration of STP factor	Power model considering the STP factor
Land and Intangible Assets (X_1)	0.335835395	0.073918	0.191688401
Fixed assets potential (X_2)	0.658054596	–0.09796	0.649508027
Current Funds Potential (X_3)	–0.480740149	–0.73453	–1.04744219
Technological staff potential (X_4)	1.176808462	2.274816	3.342263693
Potential of scientific and technological progress (X_5)	–	–	$-0.1667 \cdot e^{-0.1667 \cdot t}$

- if potential of current assets is increased by 1 %, the enterprise's net income increases by 0.4807 % providing the other factors are unchanged;
- if potential of technological personnel is increased by 1 %, the enterprise's net income increases by 1.1768 % if the other factors are unchanged;
- if the potential of technological staff is increased by 1 %, then the net income of the enterprise will increase by 2.2748 %, provided that the remaining factors remain unchanged.

The calculated elasticity ratios for the power model considering STP impacts reveal the following:

- if potential of land and intangible assets is increased by 1 %, the enterprise's net income increases by 0.1917 % providing the other factors are stable;
- if potential of fixed assets is increased by 1 %, the enterprise's net income increases by 0.6495 % providing the other factors are unchanged;
- if potential of current assets is increased by 1 %, the enterprise's net income increases by 0.0474 % providing other factors are unchanged;
- if potential of technological personnel is increased by 1 %, the enterprise's net income increases by 3.3423 % providing the other factors are unchanged.

Dynamics of the changing elasticity of the STP factor impacts on dynamics of the enterprise's net income with respect of time is demonstrated in the diagram (Fig. 2).

4. The marginal rate of substitution indicates how the factor X_j should be increased for production volumes to remain unchanged if X_j is decreased by one.

For the linear model of efficiency of production potential use, this factor is

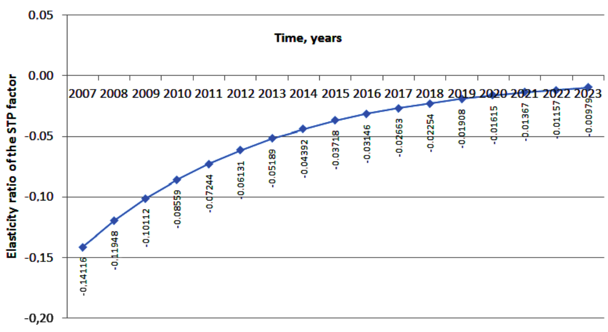

Fig. 2. Dynamics of the elasticity ratio of the power model STP factor of the PJSC "KZRK" production potential

$$h_{kj} = -a_j / a_k.$$

For the power model we have

$$h_{kj} = -\frac{a_j X_k}{a_k X_j},$$

i. e. for this model, the rate of factor substitution depends not only on parameters, but also on correlation of values of corresponding factors.

Table 8 shows the calculated values of marginal norms of substituting production potential factors.

As it seen from Table 8, not all the factors of production potential are interchangeable, only those combined in conformity with all the built models are:

- Land and intangible assets potential (X_1) – Fixed assets potential (X_2);
- Land and intangible assets potential (X_1) – Technological personnel potential (X_4);
- Fixed assets potential (X_2) – Technological personnel potential (X_4).

It should be noted that in case of the power model without considering STP impact, Potential of fixed assets (X_2) – Potential of current assets are also interchangeable factors (X_3). This indicates that this model considers possible increase in production volumes due to increased tangible expenditures and confirms that consideration of the STP factor in the model is an additional advantage enabling determination of the intensive character of production potential use.

Marginal substitution rates characterize correlation of resource use and determine the slope of isoquants for resource combinations which are components of the enterprise's production potential. We present the isoquant diagram to combine such components of production potential as Fixed assets potential – Technological personnel potential (Fig. 3).

5. Let us determine the value of general elasticity as a total of elasticities for all model factors.

For the linear model it is

$$A = 1.68995.$$

Table 8

Marginal rates of substituting production potential factors for the built models (Table 1)

Linear model				
X_2	X_1	X_2	X_3	X_4
X_1	*	–0.13855	1.905699745	–0.815753821
X_2	–7.217552688	*	**13.75448832**	**–5.887746186**
X_3	0.524741635	0.072704	*	0.428059994
X_4	–1.225860025	–0.16984	2.336121137	*
Power model without consideration of STP factor				
	X_1	X_2	X_3	X_4
X_1	*	0.093705428	13.22904	–7.16434
X_2	10.67174036	*	**–141.177**	**76.45601**
X_3	0.075591272	–0.007083313	*	0.541562
X_4	–0.139580129	0.013079416	1.846511	*
Power model considering the STP factor				
	X_1	X_2	X_3	X_4
X_1	*	–0.239587008	7.274527	–4.05905
X_2	–4.173849024	*	**30.36278**	**–16.9419**
X_3	0.137465977	0.032935062	*	0.557982
X_4	–0.246362909	–0.059025352	1.792174	*

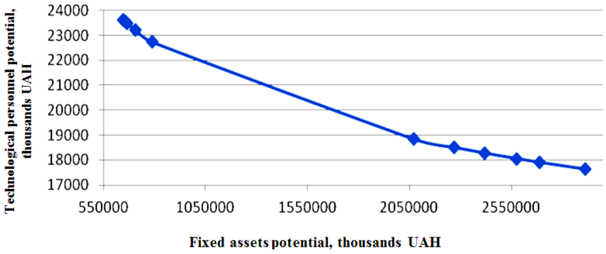

Fig. 3. The isoquant graph of components of the PJSC "KZRK" production potential power model

For the power model without considering the STP factor, it is

$$A = 1.516249.$$

For the power model considering the STP factor, it is

$$A = 3.13602 - 0.1667 \cdot e^{-0.1667 \cdot t}.$$

The calculated total elasticity indicates that when all considered factors are increased simultaneously by 1 %, the enterprise's net income changes as follows:

- for the linear model – by 1.68995 %;
- for the power model – by 1.516249 %;
- for the power model considering the STP factor – by $3.13602\,\% - 0.1667 \cdot e^{-0.1667 \cdot t}\,\%$.

The change of all the factors simultaneously as is indicated by the total elasticity factor for the linear model causes greater increase in production efficiency than the total influence of all the factors for the power model. At that, consideration of the STP impacts on development of industrial processes indicates that technological updating is a necessary and inalienable element of production potential efficiency.

All these correlations between production potential components and production volumes can be applied to managing efficiency of production processes at the PJSC "KZRK".

As decision making is always associated with evaluating a forecast (expected) value, it is essential to determine forecast characteristics of a model. To do this, out of 12 observations of the input data required for building the model of production potential efficiency, we choose the latest three observations and build a retrospective forecast to evaluate forecast quality on the basis of the built models.

We substitute the factor values in the built models of production potential efficiency for the three latest models and find the values of production volumes. Table 9 presents the obtained results.

Forecast quality is evaluated through calculating the following factors:

a) the arithmetic mean absolute error

$$MAE = \frac{|u_{10}| + |u_{11}| + |u_{12}|}{3};$$

b) the mean square error of the forecast

$$MSE = \frac{(u_{10})^2 + (u_{11})^2 + (u_{12})^2}{3};$$

c) the relative error of the forecast

$$MAPE = \frac{1}{3} \cdot \frac{|u_{10}| + |u_{11}| + |u_{12}|}{Y_{10} + Y_{11} + Y_{12}} \cdot 100;$$

d) Theil's coefficient

$$K_T = \frac{\sqrt{\frac{(u_{10})^2 + (u_{11})^2 + (u_{12})^2}{3}}}{\sqrt{\frac{Y_{10}^2 + Y_{11}^2 + Y_{12}^2}{3}} + \sqrt{\frac{\hat{Y}_{10}^2 + \hat{Y}_{11}^2 + \hat{Y}_{12}^2}{3}}}.$$

Table 10 presents values of the calculated factors of forecast quality.

The forecast errors indicate that the models of efficiency of production potential (the linear one and the power one considering the STP) possess a great forecasting potential as absolute and relative errors are insignificant and prove good approximation of the models. Theil's inequality coefficients approximate to zero, this also indicating a high-quality forecast. Comparing errors for the linear and power models, one can notice that each of them is a bit lower for the linear model, yet it does not mean that it has more advantages than the power one. The linear model does not consider a multiplicative effect of the production potential factors' interaction and is quite simple to be used under intensively growing production efficiency.

As forecast quality based on the built models is satisfactory, it is expedient to apply these models to determine forecast values of production volumes for the years to come. In order to calculate forecast values of production volumes, e.g. for the three coming years, using the developed models of production potential efficiency, it is of primary importance to determine forecast values of impacting factors Xi. We think that the increase in values of production factors for 2018 will be maintained for the three coming years and, guided by this assumption, we calculate values of production potential components. Table 11 reveals the resulting data.

The obtained forecast values of impacting factors enable forecasts for the enterprise's net income according to the built models as well as upper and lower limits of the forecasts. Fig. 4 depicts graphical representations of the forecasting results.

As the mentioned data indicate, forecast net income levels revealed through the linear and power models are not significantly different. Thus, forecasts of net income volumes based on the developed models of production potential can be the basis for making decisions as for changing the factor for the years to come.

Conclusions. Thus, the conducted analysis and modeling of efficiency of four basic factors of production potential impacting the PJSC "KZRK" production level results in three regression equations in the form of linear and power functions, as well as the power function plus an extra STP factor impact-

Table 9

Forecast values of production volumes obtained on the basis of the built models of production potential efficiency of the PJSC "KZRK" (Table 1)

Year of observation	Estimated values of production volumes		
	Linear model	Power model	Power model based on STP
2016	3 645 990.287	3 654 492	3 594 606.329
2017	4 700 384.48	5 168 699	5 178 448.086
2018	5 130 477.38	5 941 437	5 868 287.821

Table 10

Factors of evaluating forecast quality on the basis of the built models of the PJSC "KZRK" production potential (Table 1)

Indicator	Value of indicators		
	Linear model	Power model	Power model based on STP
MAE	416 741.1287	642 171.254	601 076.079
MSE	2.13572E + 11	4.21778E + 11	3.76628E + 11
MAPE	3.25 %	5.00 %	4.68 %
K_T	0.051720599	0.068999655	0.065480074

Table 11

Forecast values of the PJSC "KZRK" production potential factors (thousands UAH) (Table 1)

Year of observation	Observation number	X_1	X_2	X_3	X_4
2019	13	2479	3 137 973	243 449	1 107 793
2020	14	2713	3 362 211	308 614	1 282 949
2021	15	2947	3 586 449	373 779	1 458 105
2022	16	3181	3 810 687	438 944	1 633 261
2023	17	3415	4 2034 925	504 109	1 808 417

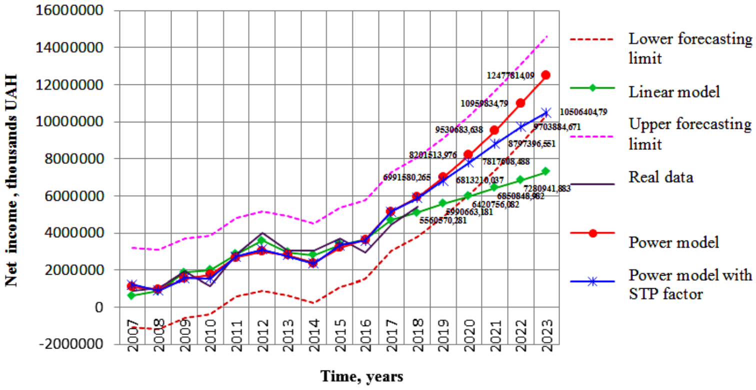

Fig. 4. Forecasts of the PJSC "KZRK" net income on the basis of the production potential models

ing the enterprise's development. All the models are proven to be adequate and reliable and can be applied to further forecasting and factor analysis of efficiency and influence of individual factors on the enterprise's net income. The authors also forecast the values of the enterprise's net income for the years to come on the basis of the developed models and check adequacy of the resulting forecasts.

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Аналіз і моделювання виробничого потенціалу підприємства залізорудної галузі Криворізького регіону

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Мета. Встановлення особливостей впливу складових елементів виробничого потенціалу гірничорудних підприємств (на прикладі ПАТ «Криворізький залізорудний комбінат») на ефективність фінансових результатів їх діяльності та формування керівництвом успішної управлінської стратегії в умовах конкурентного галузевого середовища місцевого та світового рівнів з урахуванням впливу тенденцій науково-технічного прогресу.

Методика. Моделювання й порівняльний аналіз економетричних моделей розвитку виробничого потенціалу без урахування та з урахуванням чинника науково-технічного прогресу, застосування кращих моделей для прогнозування фінансових результатів діяльності підприємства.

Результати. Побудовані адитивні й мультиплікативні моделі впливу найважливіших складових елементів виробничого потенціалу на фінансовий результат діяльності промислового підприємства гірничорудної галузі Криворізького регіону, проаналізована ефективність даних моделей. Особливу увагу приділено впливу чинника науково-технічного прогресу на результативність діяльності підприємства та враховані особливості цього впливу під час розробки програми стратегічного розвитку підприємства.

Наукова новизна. Уперше застосовано апарат економетричного моделювання для дослідження впливу складових виробничого потенціалу на результативність фінансової діяльності підприємства залізорудної галузі Криворізького регіону з урахуванням чинника науково-технічного прогресу, проведено детальний економіко-математичний аналіз результатів і виконана побудову прогнозів на основі отриманих моделей.

Практична значимість. Результати, отримані під час проведення дослідження, мають практичну цінність для керівництва великих промислових підприємств залізорудної галузі й можуть бути використані ними у процесі формування стратегічних планів управління фінансово-господарською діяльністю.

Ключові слова: *залізорудна галузь, промислове підприємство, виробничий потенціал, науково-технічний прогрес, економетричне моделювання, прогнозування фінансових результатів*

Анализ и моделирование производственного потенциала предприятий железорудной отрасли Криворожского региона

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Цель. Установление особенностей влияния составляющих элементов производственного потенциала горнорудных предприятий (на примере ОАО «Криворожский железорудный комбинат») на эффективность финансовых результатов их деятельности и формирование руководством успешной управленческой стратегии в условиях конкурентной отраслевой среды местного и мирового уровней с учетом влияния тенденций научно-технического прогресса.

Методика. Моделирование и сравнительный анализ эконометрических моделей развития производственного потенциала без учета и с учетом фактора научно-технического прогресса, применение лучших моделей для прогнозирования финансовых результатов деятельности предприятия.

Результаты. Построены аддитивные и мультипликативные модели влияния важнейших составляющих элементов производственного потенциала на финансовый результат деятельности промышленного предприятия горнорудной отрасли Криворожского региона, проанализирована эффективность данных моделей. Особое внимание уделено влиянию фактора научно-технического прогресса на результативность деятельности предприятия и учтены особенности этого влияния при разработке программы стратегического развития предприятия.

Научная новизна. Впервые применен аппарат эконометрического моделирования для исследования влияния составляющих производственного потенциала на результативность финансовой деятельности предприятия железорудной отрасли Криворожского региона с учетом фактора научно-технического прогресса, проведен детальный экономико-математический анализ результатов и выполнено построение прогнозов на основе полученных моделей.

Практическая значимость. Результаты, полученные при проведении исследования, имеют практическую ценность для руководства крупных промышленных предприятий железорудной отрасли и могут быть использованы ими в процессе формирования стратегических планов управления финансово-хозяйственной деятельностью.

Ключевые слова: *железорудная отрасль, промышленное предприятие, производственный потенциал, научно-технический прогресс, эконометрическое моделирование, прогнозирование финансовых результатов*

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