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РАЗРАБОТКА БИНОМИАЛЬНОЙ МОДЕЛИ ЦЕНООБРАЗОВАНИЯ АКЦИЙ И ОБЛИГАЦИЙ ДЛЯ СТРАХОВОЙ КОМПАНИИ НАКОПИТЕЛЬНОГО ТИПА

Проведен анализ инвестиционной деятельности страховых компаний накопительного типа. Также проанализирован процесс эволюции цен акций и создана мультипликативная модель эволюции цены облигации с заданным временем погашения и нормальной стоимости, которая описывает случайный процесс с характеристиками, близкими к броуновскому мосту.

Ключевые слова: страховой рынок, страхование жизни, накопления, броуновский мост, случайный процесс, акции, облигации, биноминальная модель.

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FINANCIAL EQUILIBRIUM AS BASIS FOR ENTERPRISE'S SUSTAINABLE DEVELOPMENT: ECONOMIC AND MATHEMATICAL FOUNDATION

Досліджено вплив фінансової рівноваги на забезпечення сталого розвитку підприємства. Розроблена економіко-математична модель, яка описує взаємозв'язок між коефіцієнтом внутрішнього зростання фінансового потенціалу, який виступає індикатором сталого розвитку підприємства, та чотирма показниками, що характеризують стан фінансової рівноваги. Отримана економіко-математична модель дозволяє прогнозувати тенденцію сталого розвитку залежно від фактичного встановлення на підприємстві фінансової рівноваги, а також моделювати ймовірні зміни його фінансового стану.

Ключові слова: *фінансова рівновага, сталий розвиток, фінансовий потенціал, фінансовий важіль, економіко-математична модель.*

1. Introduction

Ensuring the enterprise's sustainable development is an urgent problem, the solution of which will help to raise the level of management to a higher level. Smoothing of objectively conditioned cyclical downturns in the process of vital activity of an enterprise is not enough for an integrated and systemic solution of this problem. To date, the management of changes in the enterprise and the formation of conditions for sustainable development are the features of modern professional management.

One of the main conditions for ensuring enterprise's sustainable development is financial equilibrium.

2. The object of research and its technological audit

The object of research is the process of forming an enterprise's sustainable development for achieving its financial equilibrium. The mechanism of this relationship is realized through financial potential, which is a consequence of financial equilibrium and the cause of enterprise's sustainable development. However, building financial capacity should not be an end in itself [1]. Therefore, the key is the question of the need to ensure the conditions for building the financial capacity of the enterprise to ensure sustainable development. This basic condition is the financial equilibrium.

The study of financial equilibrium of the enterprise by foreign scientists corresponds to the term «financial health», which in translation means «financial health» [2, 3]. For its evaluation by foreign economic science, the discriminative models have been developed [4, 5]. In the practice of domestic enterprises, they can be used to predict bankruptcy, that is, a diametrically opposite state of sustainable development. In the absence of signs of bankruptcy, a conclusion is made about the success of the enterprise.

The originality of our study lies in the fact that our model has not only to state the absence of bankruptcy. It provides for the establishment of the interdependence of sustainable development on the state of financial equilibrium of the enterprise. A certain object of research is studied on the example of machine-building enterprises of Ukraine.

3. The aim and objectives of research

The aim of research is development of an economic and mathematical model that allows to assess the impact

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of financial equilibrium on the enterprise's sustainable development.

To achieve this aim, the following objectives are defined:

1. To give a methodological explanation of the relationship between financial equilibrium and enterprise's sustainable development.

2. Provide an economic and mathematical justification for the relationship between financial equilibrium and enterprise's sustainable development in the form of a model.

3. To substantiate the practical suitability of the developed economic-mathematical model.

4. Research of existing solutions of the problem

Financial equilibrium is considered as an internal factor of development of the financial and economic potential of the enterprise that increases its adaptability to changes in the modern market environment [6].

The formed strong financial potential, in the case that the financial equilibrium is ensured, is the material basis for achieving high efficiency of the enterprise's activity [1].

This means that support in the dynamics of financial equilibrium contributes to the enterprise's sustainable development. Thus, conditions are provided for the progressive increase of the financial potential of the enterprise and its effective use. This conclusion correlates with the theory of sustainable economic growth. In accordance with this theory, the financial equilibrium of the enterprise in the process of its development is one of the main tasks of financial management, the implementation of which allows to form long-term trends of enterprise's sustainable development [7].

The world economic science considers sustainable development mainly in the context of social, rather than economic processes [8]. Domestic economic science has formed only a theoretical basis for the study of the financial content of sustainable development. It is about certain principles of enterprise's sustainable development, providing for the integrity and balance of the operating, investment and financial activities of the enterprise are ensured, in particular, by maintaining financial equilibrium [9].

Modern foreign economic science raises the question of the need to develop criteria for assessing the enterprise's sustainable development and the formation of special reporting on these indicators [10]. However, the existing foreign tools in this area are aimed at determining the enterprise's sustainable development as a state of absence of threat of bankruptcy [11, 12]. Its application allows only to ascertain the existence of sustainable development. At the same time, questions remain unanswered: «What is the economic level of the enterprise's sustainable development?», «How has it changed in the dynamics in recent years?», «What triggered the change in the level of sustainable development?».

In this connection, the aim of research in this article is an actual scientific and practical point of view. Based on the results of its achievement, it is planned to expand the toolkit for assessing the enterprise's sustainable development taking into account economic factors, namely, the state of financial equilibrium.

5. Methods of research

To solve the problems, the following methods are used: dialectics, induction, coefficient analysis, comparisons, correlation regression analysis, trend analysis, graphical, logical generalization.

6. Research results

The development of an economic-mathematical model for assessing the impact of the financial equilibrium on ensuring the enterprise's sustainable development is based on the use of correlation-regression analysis. For this study, data on financial statements on the financial indicators of twenty-five machine-building enterprises of Ukraine calculated on their basis (Table 1) are collected.

One of the indicators of enterprise's sustainable development is the coefficient of internal growth of financial potential. In our model, it is an effective sign and is denoted by the symbol (Y). This indicator characterizes the intensity of the enterprise's financial capacity building through reinvestment of profits.

Variable factors of this model are:

1. The first indicator of financial equilibrium (X_1) is calculated as the ratio of equity to property in non-monetary form. On economic content, this indicator characterizes the level of mobility of own capital. The value of this indicator above 1 shows the share of own capital in liquid form.

2. The second indicator of financial equilibrium (X_2) is calculated as the ratio of property in cash to liabilities. It describes the adequacy of the enterprise's liquidity reserve for debt repayment. The value of this indicator should exceed 1. In this case, the liquidity reserve is sufficient to cover all liabilities.

3. The financial lever in assets (X_3) is calculated as the ratio of cash and non-cash assets. The monetary assets include: accounts receivable, financial investment and cash. Other assets have a monetary form (for example, based on funds, stocks, capital investments, investment property). This financial lever shows the liquidity level of the enterprise's assets.

4. The financial lever in the capital (X_4) is calculated as the ratio of liabilities to equity. On economic content, this indicator refers to a group of criteria that characterize the financial stability of the enterprise. The higher this financial lever, the greater the dependence of the enterprise on creditors.

Calculation of the coefficients and characteristics of the four-factor model is carried out using the method of least squares and mathematical functions of the Excel spreadsheet.

The calculation of the matrix of coefficients of pair correlation is of interest for economic interpretation (Table 2).

An analysis of the pair correlation coefficients makes it possible to determine factors that can't be included together in the model. The obtained results show that the closest relationship is observed between the coefficient of internal growth of the financial potential (Y) and the first (X_1) and second (X_2) financial equilibrium indicators, according to 0.89105 and 0.89027. Relationship between the second indicator of financial equilibrium (X_2) and the financial lever in assets (X_3) is significant. Both these indicators characterize different aspects of the liquidity equilibrium. Achieving a balance of liquidity is the first step in establishing a financial equilibrium.

Table 1

Indicators of financial equilibrium and sustainable development of engineering enterprises of Ukraine as of 01.01.2017

Enterprise	The coefficient of internal growth of financial potential (Y)	The first indicator of financial equilibrium (X_1)	The second indicator of financial equilibrium (X_2)	Financial lever in assets (X_3)	Financial lever in the capital (X_4)
PJSC «Dniprovazhmash»	0.137	0.522	0.697	1.099	3.021
PJSC «Energomashspetsstal»	–0.634	–1.566	0.036	0.096	–1.700
PJSC «Auto CrAZ»	–0.091	0.092	0.851	5.180	65.866
PJSC «Motor Sich»	1.575	0.808	0.566	0.250	0.546
PJSC «Poltava Automobile Unit Plant»	–0.145	–0.960	0.754	6.000	–8.293
PJSC «Turboatom»	2.080	1.203	1.539	0.749	0.404
PJSC «Zapiporozhtransformator»	–0.585	–3.235	0.259	1.482	–1.767
PJSC «Dnipro mashine–building plant»	0.001	0.650	0.896	2.998	5.150
PJSC «Dneprovagonmash»	7.613	7.911	11.13	7.593	0.086
PJSC «GRETA»	0.541	0.580	0.570	0.556	1.681
PJSC «Poltavamash»	0.008	0.452	0.315	0.252	1.769
PJSC «Kharkiv Bearing Plant»	–0.461	–0.565	0.130	0.234	–3.185
PJSC «Poltava Turbomechanical Plant»	0.815	1.056	1.106	0.583	0.499
PJSC «KryukovskyRailway Car Building Works»	–0.085	1.229	1.272	1.069	0.684
PJSC «Umanfermmash»	0.153	0.742	0.508	0.267	0.707
PJSC «Tutkovsky	0.076	0.602	0.323	0.190	0.975
PJSC «Steklopribor»	2.421	2.482	2.816	2.297	0.329
PJSC «Melitopol compressor»	–0.106	1.224	1.418	0.760	0.438
PJSC «Ukrainsky grafit»	0.228	0.528	0.378	0.287	1.440
PJSC «Nasosenergomash»	1.406	0.986	0.963	0.374	0.393
PJSC «InterpipeNMPP»	0.215	1.069	1.027	2.638	2.402
PJSC «Romny factory Traktorozapchast»	1.361	1.149	1.377	0.544	0.344
PJSC «Prigma–Press»	0.117	0.829	0.477	0.156	0.395
PJSC «Verkhnodniprovsk Mashine–building plant»	0.810	1.692	4.949	0.867	0.104
PJSC «Odesskiy machine building plant»	–0.490	–0.133	0.134	0.176	–9.831

Note: Calculated by the author according to the financial statements of enterprises [13].

Table 2

Matrix of pair correlation coefficients $r_{(i,j)}$

Factors	X_{1i}	X_{2i}	X_{3i}	X_{4i}	Y
X_{1i}	1	0.86521	0.44462	–0.00995	0.89105
X_{2i}	–	1	0.60961	–0.02744	0.89027
X_{3i}	–	–	1	0.34661	0.52067
X_{4i}	–	–	–	1	–0.05890
Y	–	–	–	–	1

Table 3 presents the characteristics of the results of the estimation of tightness and the direction of the relationship between the factors of this model.

An evaluation of the relationship tightness indicates the absence of the functional relationship model between the factors. This means that all the relationships between the factors included in the model are stochastic. Therefore, it is methodologically correct to conduct research using correlation-regression analysis.

Table 3

Tightness and direction of the relationship between variables using the «Chaddock scale»

Pair correlation coefficient between variables	The boundaries of the modular value of the correlation coefficient	Tightness of relationship	Direction of relationship
$r(X_1, X_2) = 0.86521$	$0.7 < \|r_{ij}\| < 0.9$	Strong relationship	Direct relationship
$r(X_1, X_3) = 0.44462$	$0.3 < \|r_{ij}\| < 0.5$	Moderate relationship	Direct relationship
$r(X_1, X_4) = -0.00995$	$0.1 > \|r_{ij}\|$	Very weak relationship	Back relationship
$r(X_1, Y) = 0.89105$	$0.7 < \|r_{ij}\| < 0.9$	Strong relationship	Direct relationship
$r(X_2, X_3) = 0.60961$	$0.5 < \|r_{ij}\| < 0.7$	Significant relationship	Direct relationship
$r(X_2, X_4) = -0.02744$	$0.1 > \|r_{ij}\|$	Very weak relationship	Back relationship
$r(X_2, Y) = 0.89027$	$0.7 < \|r_{ij}\| < 0.9$	Strong relationship	Direct relationship
$r(X_3, X_4) = 0.34661$	$0.3 < \|r_{ij}\| < 0.5$	Moderate relationship	Direct relationship
$r(X_3, Y) = 0.52067$	$0.5 < \|r_{ij}\| < 0.7$	Significant relationship	Direct relationship
$r(X_4, Y) = -0.05890$	$0.1 > \|r_{ij}\|$	Very weak relationship	Back relationship

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The results of the comparison of the pair correlation coefficients, calculated between the variables of the final model, with the magnitude of the multiple correlation coefficient (0.3961) prove that there are pairs of related variables in the array (Table 4).

Table 4

Comparison of paired correlation coefficients with a multiple correlation coefficient

The size of the pair correlation coefficient	Comparison (<,>)	Variables	Characteristic of relationship between variables
$r(X_1, X_2)=0.86521$	$\|r_{1,2}\|>r_{cr}=0.3961$	variables X_1 and X_2	related
$r(X_1, X_3)=0.44462$	$\|r_{1,3}\|>r_{cr}=0.3961$	variables X_1 and X_3	related
$r(X_1, X_4)=-0.00995$	$\|r_{1,4}\|>r_{cr}=0.3961$	variables X_1 and X_4	not related
$r(X_1, Y)=0.89105$	$\|r_{1,Y}\|>r_{cr}=0.3961$	variables X_1 and X_Y	related
$r(X_2, X_3)=0.60961$	$\|r_{2,3}\|>r_{cr}=0.3961$	variables X_2 and X_3	related
$r(X_2, X_4)=-0.02744$	$\|r_{2,4}\|<r_{cr}=0.3961$	variables X_2 and X_4	not related
$r(X_2, Y)=0.89027$	$\|r_{2,Y}\|>r_{cr}=0.3961$	variables X_2 and Y	related
$r(X_3, X_4)=0.34661$	$\|r_{3,4}\|<r_{cr}=0.3961$	variables X_3 and X_4	not related
$r(X_3, Y)=0.52067$	$\|r_{3,Y}\|>r_{cr}=0.3961$	variables X_3 and Y	related
$r(X_4, Y)=-0.05890$	$\|r_{4,Y}\|<r_{cr}=0.3961$	variables i X_4 and Y	not related

However, the presence of bound variables is not a consequence of multicollinearity. This means that in an array of variables, the influence of the factor is not regarded as determining the comparison with others. Therefore, an assessment of the tightness of the relationship of the variables among themselves makes it possible to conclude that the selected factors can be included in one model.

As a result of calculations, the indicators of the economic-mathematical model are obtained (Table 5):

Table 5

Indicators of the economic-mathematical model for assessing the impact of financial equilibrium on ensuring the sustainable development of a machine-building enterprise

Coefficients of the model	Weighted coefficients of the model	Standard errors of the coefficients of variables	*t*-test for the coefficients of the model	Coefficients of elasticity (*Ki*)
a_0	–0.1450	0.1763	–0.8223	*x*
a_1	0.4507	0.1560	2.8889	0.5142
a_2	0.2964	0.1499	1.9774	0.6029
a_3	0.0586	0.1037	0.5652	0.1268
a_4	–0.0082	0.0118	–0.6929	–0.0302

Let's characterize the parameters of the economic-mathematical model (1).

$$Y = -0,145 + 0,4507 \cdot X_1 + 0,2964 \cdot X_2 + \\ + 0,0586 \cdot X_3 - 0,0082 \cdot X_4. \quad (1)$$

1. With the growth of the first financial equilibrium indicator (X_1) by 1 in the conditions of invariability of other factors, the coefficient of internal growth of the financial potential (Y) increases by an average of 0.4507.

2. The increase in the second financial equilibrium indicator (X_2) by 1 in the conditions of the invariability of other factors causes an increase in the coefficient of internal growth of the financial potential (Y) by an average of 0.2964.

3. The growth of financial leverage in assets (X_3) by 1 in the conditions of the invariability of other factors leads to an increase in the coefficient of internal growth of the financial potential (Y) by an average of 0.0586.

4. The growth of financial leverage in capital (X_4) by 1 in the conditions of the invariability of other factors causes a decrease in the coefficient of internal growth of the financial potential (Y) by an average of 0.0082.

To perform a comparative assessment of the influence of factors on the coefficient of internal growth of the financial potential of the enterprise, it becomes necessary to normalize the regression coefficients by calculating β-coefficients.

After reducing the regression coefficients to a comparable form, the regression equation is obtained in a standardized form (2):

$$Y = 0,5142 \cdot X_1 + 0,6029 \cdot X_2 + 0,1268 \cdot X_3 - 0,0302 \cdot X_4. \quad (2)$$

Equation (2) shows that both indicators of financial equilibrium have the greatest influence on the coefficient of internal growth of the financial potential of an enterprise. Their influence is significant for the influence of other factors more than five times. The obtained conclusions are confirmed by the results of an assessment of the relationship tightness of the factors included in the economic-mathematical model (1).

Let's carry out a statistical description of the economic-mathematical model (1) according to the data in Table 6.

Table 6

Parameters for the characterization of the economic and mathematical model for evaluating the influence of the financial equilibrium on ensuring the sustainable development of a machine-building enterprise

Indicator	Value
Coefficient of determination	0.8546
Fisher test	29.3912
Table value of the Fisher test (error 0.01)	4.4307
Table value of the Student's test (error 0.05)	2.0687
Table value of the Student's test (error 0.1)	1.7139
Table value of the Student's test (error 0.5)	0.6853
Table value of the Student's test (error 0,6)	0.5318
Number of degrees of freedom	20
Standard regression error	0.6925

The value of the multiple coefficient of determination ($R^2=0.8546$) shows that the change in the coefficient of internal growth of the financial potential of the enterprise by 85.46 % is determined by the influence of factors included in the model, and by 14.54 % – by the influence of other factors unaccounted for by the model. The reliability of the obtained values of the weight coefficients in the model is indicated by the results of comparing the *t*-criteria of each factor «X_i» with the tabulated value of

the Student's test with different significance levels ranging from 40 % to 95 % and the number of degrees of freedom 20. Thus, in absolute terms, the t-test the weight coefficient $a_1$is the table value of the Student's test result, which is equal to 2.0687. This means that the value of a_1 is reliable with a probability of 95 %. At the same time, let's observe that the *t*-test of other weighting coefficients is of low significance. Thus, the value of a_2 is reliable with a probability of 90 %, the values of a_0 and a_4 are 50 % reliable, a_3 is reliable with a probability of 40 %. Such discrepancy in the reliability of the weight coefficients of the model is explained by the wide variability of the tightness of the relationship between the factors, which is typical for stochastic dependencies. According to the Fisher criterion, it is possible to state that with a probability of 99 % the model is reliable, since $F=29.3912$ is greater than $F_{tab}=4.4307$.

Practical application of the developed economic-mathematical model (1) will be carried out according to the data of PJSC «Motor Sich». For this, Table 7 presents the calculated financial equilibrium indicators of the given enterprise for 2012–2016.

The forecast value of the coefficient of internal growth of the financial potential of PJSC «Motor Sich» is determined by substituting the values of the indicators of the state of its financial equilibrium in the economic and mathematical model (1). Let's show the forecasted dynamics of the sustainable development index of PJSC «Motor Sich» on the chart (Fig. 1).

Despite the stable profitability of PJSC «Motor Sich», one should point out a long-term imbalance in the financial equilibrium. During 2012–2016 at the enterprise negative value of the monetary capital with a characteristic tendency to growth of deficiency of liquidity takes place. This is evidenced by the importance of the first indicator of financial equilibrium, which is steadily less than one. The imbalance in the structure of the sources of formation and areas of use of the financial potential of PJSC «Motor Sich» is characterized by the excess of the financial leverage in the capital over the amount of the financial lever in the assets.

So, at the enterprise, the growth of liabilities is not ensured by an adequate increase in liquid assets. This is the reason for the emergence of problems in the area of solvency and financial stability of PJSC «Motor Sich».

Confirmation of the conclusion about the violation of the principles of sustainable development in PJSC «Motor Sich» is evident from the ratio of the indicators of the equilibrium financial state. At the enterprise during 2012–2016 stable inequality: $I^{II}<I^{I}<1$. This is a sign of the imbalance in the structure of the sources of formation and areas of use of the financial potential of PJSC «Motor Sich». The revealed non-critical violations of the financial equilibrium signal a slow decline in the trend of sustainable development of PJSC «Motor Sich». The development of an operational crash-program will allow to level the negative trend in the activity of the enterprise.

Table 7

Indicators of the financial equilibrium and sustainable development of PJSC «Motor Sich» for 2012–2016

Indicators	2012	2013	2014	2015	2016
The first indicator of financial equilibrium (X_1)	0.885	0.911	0.857	0.861	0.808
The second indicator of financial equilibrium (X_2)	0.737	0.772	0.690	0.649	0.566
The financial lever in assets (X_3)	0.322	0.300	0.320	0.257	0.250
Financial lever in the capital (X_4)	0.493	0.427	0.540	0.461	0.546
The forecast value of the coefficient of internal growth of the financial potential (Y)	0.564	0.580	0.536	0.508	0.457

Note: Calculated by the author according to the financial statements of PJSC «Motor Sich» [13].

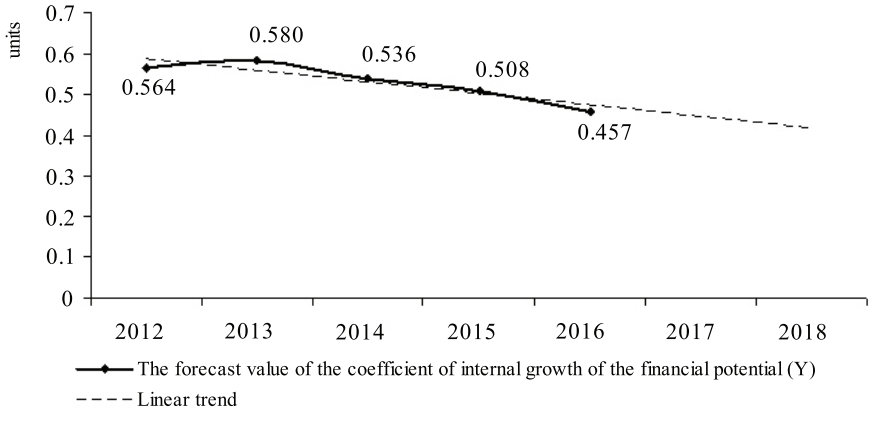

Fig. 1. Dynamics of sustainable development of PJSC «Motor Sich» for 2012–2016 and its projected trend for 2017–2018

7. SWOT analysis of research results

Strengths. The strength of this research is obtaining a new tool for assessing the impact of financial equilibrium on the sustainable development of a machine-building enterprise, what is the economic-mathematical model (1). It allows to model possible scenarios for development of events in the financial state of a machine-building enterprise and to predict the dynamics of its development. Its practical application will help to increase the validity level of management decisions in the sphere of financial management of a machine-building enterprise.

Weaknesses. The weakness is that the developed model is suitable for use only in machine-building enterprises.

Opportunities. The opportunities for further research are development of similar economic and mathematical models for enterprises of other industries.

Threats. The threats to the results of conducted research are that the variability of the conditions for development of the activities of engineering enterprises is high-frequency. Over time, it may be necessary to revise the factors included in the model.

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8. Conclusions

1. Considering sustainable development as a process that results in a number of quantitative and qualitative changes in the financial potential of the enterprise, it is possible to conclude that the implementation of such reforms requires a stable financial equilibrium in time. The fulfillment of this task refers to the functions of the economic security system, whose aim is ensuring the stable functioning and progressive social and economic development of the enterprise.

2. The obtained economic-mathematical model describes the dependence of the enterprise's sustainable development on the state of its financial equilibrium. A productive index of this model is the coefficient of internal growth of the financial potential of the enterprise. Factors, whose influence is studied on the result indicator, cover all levels of financial equilibrium formation at the enterprise. The economic-mathematical model (1) describes 85.46 % of the values of the effective indicator. The reliability of this model is set at 99 %. According to the Fisher criterion, it is possible to state that with a probability of 99 % the model is reliable, since $F=29.3912$ is greater than $F_{tab}=4.4307$.

3. Given the high reliability characteristics of the economic-mathematical model, it is possible to conclude that it is suitable for its use in order to predict the dynamics of sustainable development of a machine-building enterprise by substituting the probable values of indicators characterizing the state of achieving financial equilibrium. The results of application of the economic-mathematical model (1) by the example of PJSC «Motor Sich» confirm its practical suitability for its use with the aim of improving the quality of financial management.

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ФИНАНСОВОЕ РАВНОВЕСИЕ КАК ОСНОВА УСТОЙЧИВОГО РАЗВИТИЯ ПРЕДПРИЯТИЯ: ЭКОНОМИКО-МАТЕМАТИЧЕСКОЕ ОБОСНОВАНИЕ

Исследовано влияние финансового равновесия на обеспечение устойчивого развития предприятия. Разработана экономико-математическая модель, которая описывает взаимосвязь между коэффициентом внутреннего роста финансового потенциала, выступающего индикатором устойчивого развития предприятия, и четырьмя показателями, характеризующими состояние финансового равновесия. Полученная экономико-математическая модель позволяет прогнозировать тенденцию устойчивого развития в зависимости от фактического установления на предприятии финансового равновесия, а также моделировать возможные изменения его финансового состояния.

Ключевые слова: финансовое равновесие, устойчивое развитие, финансовый потенциал, финансовый рычаг, экономико-математическая модель.

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