ISSN: 0798-1015

REVISTA ESPACIOS

Vol. 41 (34) 2020 • Art. 17

Recibido/Received: 22/06/2020 • **Aprobado**/Approved: 15/08/2020 • **Publicado**/Published: 10/09/2020

Modeling of economic sustainability of enterprise development

Modelización de la sostenibilidad económica del desarrollo empresarial

BAGROVNIKOVA, Svetlana V.[1]
BAGROVNIKOVA, Alina N.[2]

Abstract
The purpose of this research is to develop a model of the economic sustainability of the development of the enterprise with the possibility of a point interpretation of the effective indicator. The article proposes to use the binary logistic regression method, which allows to categorize the enterprise as “sustainable” or “unstable” with a certain probability. The analysis was conducted using database of 20 Russian engineering enterprises of the Volga Federal district and Ural Federal District in 2015-2017.
key words: sustainable development, economic sustainability, industrial enterprises, binary logistic regression.

Resumen
El propósito de esta investigación es desarrollar un modelo de sostenibilidad económica del desarrollo de la empresa con la posibilidad de una interpretación puntual del indicador efectivo. El artículo propone utilizar el método de regresión logística binaria, que permite clasificar la empresa como "sostenible" o "inestable" con una cierta probabilidad. El análisis se realizó utilizando una base de datos de 20 empresas de ingeniería rusas del distrito federal del Volga y del distrito federal de los Urales en 2015-2017.
Palabras clave: desarrollo sostenible, sostenibilidad económica, empresas industriales, regresión logística binaria.

1. Introduction

Functioning of the enterprise in modern economic conditions occurs with continuous changes of the external environment. In modern Russia factors of the external environment of indirect influence have a special impact on the state of the economics: resource provision of enterprises, level of social, economic and political intensity, crisis trends in global economy. Continuous impact of these factors on the enterprises and economy in general negatively affects all aspects of the enterprise activities, slows down its development. Nevertheless, universal trends of functioning of economic systems are directed to strengthening of the state economic capacity due to the increase in labor productivity and labor potential, rational use of natural resources, decrease in negative

[1] Ph.D. in Philosophy, Associate Professor at the Department of Philosophy and Sociology, Kalashnikov Izhevsk State Technical University, 426069, 7 Studencheskaya st., Izhevsk, Russia. svetwladi@gmail.com
[2] Master in Finance, Senior Lecturer at the Department of Economics and Management of the Organization, Kalashnikov Izhevsk State Technical University, 426069, 7 Studencheskaya st., Izhevsk, Russia. redmarceline679@gmail.com

impacts on the environment, aspirations to the development of the human capital. The data set of those provisions can be characterized as an aspiration to the sustainable development of the state and society.

Nowadays the sustainable development concept is the cornerstone of activity of each economic subject. It occurs because the scientific and technical progress accompanied with industrialization carries the destructive, harmful to the environment, pattern, and the concept of sustainable development, on the contrary, is designed to solve global problems of mankind, eliminating the depletion of natural resources and keeping it for the subsequent generations. Also, an important part is played by the fact that most of the domestic industrial enterprises apply standard administrative and managerial concepts and techniques on practice, disregarding variability and instability of the external environment without taking into consideration the possible consequences of the influence of its negative factors.

Thus, there is a need for creation of the sustainable development control system of the enterprise. The sustainable development control system of the enterprise is directed to realization of the actions allowing to estimate the current state and to predict the main functioning options of the enterprise taking into account positive and negative impact of factors of the internal and external environment.

1.1. Historical premises

The idea of the sustainable development was introduced for the first time at the beginning of the 20th century by Vernadsky. However, it should be noted that since that moment the interpretation of this term underwent various significant changes. Ursul (2005) gives the definition of the sustainable development concept as follows: "Sustainable development is the operated system-balanced socio-natural development which does not destroy the surrounding environment but provide survival and safe and vaguely long existence of a civilization" (Sustainable development: a conceptual model, p. 60). Thus, the mankind is capable of meeting the present requirements without prejudice to the subsequent generations to meet those needs in the future (Ursul, 2013, National Idea and Global Processes: Security, Sustainable Development and Noospherogenesis, pp. 1-66). That means the possibility of the combination of scientific and technical progress to indefinitely long safe existence of mankind, the increase in the standard of living and the solution of environmental problems (Saquet, 2005, World Atlas of Sustainable Development: Economic, Social and Environmental Data).

Scientific research in the field of economics, sociology, theory of evolution and ecology (Weber, 1990; Ursul et al., 2012) represents the process of transition to sustainable development as follows.

1. Every system in the process of its development undergoes some global or minor changes, which leads to the stability loss. The loss of stability is caused by internal changes in the system or external influence.

2. Internal or external changes are usually accompanied by the appearance of a new element in the system. The result of this is the instability of the system, which leads to the fact that the system subsequently self-organizes.

3. As soon as a self-organization occurs, the system enters a new, previously non-existent state. From the point of view of evolution, we can talk about the emergence of a new system cycle.

Thus, the emergence of global problems initially leads to an unstable state of the system, but the subsequent self-organization of the structure of the system elements leads to the sustainable development in the future, thereby bringing society to a new level. Then the appearance of new elements occurs, which again leads to instability, and the cycle repeats (Bagrovnikova, 2017). In other words, the system is constantly becoming more complex and refined, reaching a new, highest level of complexity, in which society is viewed not as a system isolated from nature, but as its non-separable part developing due to the constant exchange of energy, substance and information with the natural environment (Botkin et al., 2014, Features of the Study on the Sustainable Development of the Enterprise in the Processes of Globalization, pp. 41-48).

1.2. Theoretical considerations

In the historical context, the sustainable development consists of the following, interrelated factors: the condition of the technosphere, the surrounding external environment (ecosphere), and society. In 1992, the Rio Declaration on Environment and Development reflected the principle of interaction between these categories, which led to the research of conditions that would provide a simultaneous solution of the problems of economic growth while maintaining the stability of the social and environmental situation, thereby forming the concept of sustainable development in the world community. We would want to consider some significant theoretical approaches to the concept of the sustainable development:

1) the sustainable development is a forward-looking model in which the vital needs of the current generation of mankind are met without harming the opportunities left to future generations to satisfy their own needs (Declaration of the United Nations Conference on the Human Environment, Stockholm, Sweden, 1972);

2) the sustainable development is a model of the progressive development of the society, which satisfies the vital needs of the current generation without depriving such a possibility of future generations of the mankind (World Commission on Environment and Development, or the Commission of the Prime Minister of Norway Gro Harlem Brundtland, 1983);

3) the sustainable development is the managing of the total capital of the society in the interests of preserving and enhancing human capabilities (World Development Report, 2003, Sustainable Development in a Dynamic World, World Bank, NY);

4) the sustainable development is the harmonious development of the production, the social sphere, the population and the environment (Presidential Decree of 1 April 1996 No. 440 “On the Concept of the Russian Federation Transition to Sustainable Development”).

Based on the approaches mentioned above, it should be noted that the world community is focused on the globalization and sustainable development while preserving the resource base, ensuring that the needs of the current generation are met without harming future generations, and achieving economic and social equilibrium.

1.3. Sustainable development of the enterprise: features and characteristics

The most common concepts characterizing the sustainability of the enterprise are financial and market stability. According to the established system of indicators, the financial stability is determined by the ratio of the absolute indicators of the balance sheet of an enterprise, and the market stability is characterized by a system of indicators (coefficients) having a normal value. At the same time, the correspondence of the values of balance indicators to the standard (normal) values characterizes the enterprise as sustainable. In addition, there is also an economic sustainability, or the ability of an enterprise to maintain financial stability in the constantly changing market conditions through the improvement and purposeful development of its production, technological and organizational structure with the application of the logistic-oriented management methods (Menzheres, 2002, Sustainable Functioning of the Enterprise in the Infrastructure of the Regional Market: Theory and Methodology, pp. 124-132).

Thus, it is possible to evaluate the functioning of the enterprise for each type of sustainability. Herewith, a system of indicators of the sustainable development of an enterprise is determined, their standardization is completed, and an integral indicator of the sustainability of the development is calculated. The determination of the integral indicators of each type of the sustainability allows to identify a certain type of the sustainability when planning certain changes and to create the basis for the effective management decision-making during the period of enterprise development.

The transition of enterprises to the sustainable development becomes impossible without observing the following fundamental points:

a) the process of the sustainable development should be regulated by the government;

b) the capabilities of the self-sufficiency of the economy, such as production, scientific, technical and intellectual potential, and economic resources should be used at the highest level (Evie et al., 2001, Earth Council. Guidelines for NCSD Rio +10 assessment, San Jose);

c) the concept of the sustainable development should be inspected taking into account the current specific situation;

d) the priority of the development directions should be identified;

e) the optimal combination of the state and market regulation and the state stimulation of qualitative changes should be presented.

The above provisions allow the authors to note that in order to effectively manage the sustainable development of enterprises, it is necessary to analyze the socio-economic and environmental situation, which later allows finding effective tools to achieve the goals of the sustainable development. Criteria characterizing the conditions for ensuring the sustainable development can be described as follows: "economic growth - environmental quality", "economic balance with the natural environment", "socio-ecological and economic coherence in the development". Ensuring the effective management of the sustainable development of enterprises requires the development of the above-mentioned and other fundamentally new criteria.

2. Methodology

The concept of the sustainable development is aimed at ensuring the stability of the noosphere, ecosphere and technosphere, improving the quality of life of the society and the preservation of natural resources for the livelihood of future generations. Currently, the term "sustainable development" has received an extensive application on enterprises to characterize the efficiency of their performance from the social, economic and environmental side. The assessment of economic sustainability in domestic and foreign studies is mainly conducted using various methods based on multiple discriminant analysis. At the same time, the principles of the selection of indicators included in those methods are rather subjective, and the effective indicator has an interval rather than a point (probabilistic) interpretation.

2.1. Data and methods

Currently, there are many approaches of determining the financial and economic state (Sajfulin & Kadykov, 1996, Rating Rapid Assessment of the Financial Condition of the Company According to Public Reporting) and the economic sustainability of the enterprise development (Sheremet, 2006; Zhukova, 2012; Khudyakova, 2016), presented in the form of a multiplicative or additive model based on the multiple discriminant analysis. Most models are based on fundamental, in our opinion, works, mostly aimed at determining the sustainability or insolvency of the company (Altman, 1968; Taffler & Tisshaw, 1977; Springate, 1978; Olson, 1980; Fulmer et al., 1984; Adams, 1999; Altman, 2005). Nevertheless, some shortcomings of these methods should be noted, in particular, the lack of sectoral and regional differentiation of indicators included in the model, discrepancy in the criteria for the selection of indicators, interval, rather than the point estimate of the effective indicator. In view of the above, we propose to evaluate the economic sustainability of the enterprise development based on the binary logistic regression method.

A distinctive feature of this method is that the dependent variable is binary (in other words, it can possess only two values, for example, 0 or 1). With the application of the logistic regression model, one can estimate the probability of the occurrence of a certain event (for example, possible bankruptcy, loan repayment, etc.). This could be achieved by applying the following regression equation (logit model)

$$P = \frac{1}{1 + e^{-y}}$$

where P is the probability of occurrence, e is the base on the natural logarithm 2.71…, and y is linear predictor function ($y = a + b_1x_1 + b_2x_2 + \cdots + b_nx_n$).

The following advantages of the binary logistic regression method can be distinguished:

1) the probability of the occurrence of an event is estimated for a specific observation;

2) it is possible to use a variable of any type as a covariate;

3) nonlinearity allows to include independent variables (covariates) in the interaction model.

Nowadays the problem of the economic sustainability of the enterprise development assessment cannot be considered completely resolved for the following reasons:

- the application of different methods in relation to one enterprise leads to contradictory results;

- the forecast accuracy of models is significantly reduced when applying a data collected for several years before signs of financial and economic insolvency appear;

- in the models data of the current year are applied, and the retrospective dynamics of change in indicators is not taken into account.

Table 1 shows collective results of the analysis of 20 Russian industrial enterprises of the Volga Federal District and Ural Federal District in 2015-2017. The analysis was based on the following methods: Altman Z-score (Altman, 1968), Irkutsk State Economic Academy model (1999), Taffler-Tisshaw model (Taffler & Tisshaw, 1977), Springate score (Springate, 1978), Saifullin-Kadykov model (Saifullin & Kadykov, 1998), Postushkov model (Postushkov, 1999), Lis model (Lis, 1972). The data obtained demonstrate that the economic statuses of 2 enterprises in 2015, 3 enterprises in 2016 and 3 enterprises in 2017 were defined as sustainable, and the economic statuses of 5 enterprises in 2015, 2 enterprises in 2016 and 1 enterprises in 2017 were assessed as unstable, while other enterprises received a rather contradictory characteristics.

Table 1
Collective data results of the sustainability analysis of industrial enterprises based on 7 models in 2015-2017

Result Characteristics	Number of enterprises			
	2015	2016	2017	Total
0 model described the status of the enterprise development as “sustainable”	5	2	1	**8**
1 model described the status of the enterprise development as “sustainable”	2	6	3	**11**
2 models described the status of the enterprise development as “sustainable”	2	1	5	**8**
3 models described the status of the enterprise development as “sustainable”	1	2	2	**5**
4 models described the status of the enterprise development as “sustainable”	3	1	3	**7**
5 models described the status of the enterprise development as “sustainable”	2	4	2	**8**
6 models described the status of the enterprise development as “sustainable”	3	1	1	**5**
7 models described the status of the enterprise development as “sustainable”	2	3	3	**8**
Total	20	20	20	**60**

Source: authors

Thus, based on the data processing of industrial enterprises of the Volga Federal District and Ural Federal District, the authors propose to develop their own methodology, which makes it possible to classify the enterprise as “sustainable” or “unstable”. The developed model should have a score calculated based on the main indicators of the enterprise activity, which allows drawing conclusions about the sustainable development or risk of the instability of the enterprise.

2.2. Static Model

For this type of model building based on the statistical data, we apply the binary logistic regression method. In order to choose indicators that can act as an explanatory variable (regressors) in the model, it is necessary to identify such indicators, the values of which are significantly different for the chosen enterprises. We have chosen the tools used to solve this problem, such as correlation analysis, contrast of means tests and non-parametric statistical hypothesis tests.

We assign the criterion “sustainably developing” to an enterprise if it was recognized as such by 4 out of 7 models which we examined in Table 1. In other cases, we hypothesize about the instability of the enterprise. For the construction and practical approval of such models indicators of 20 engineering enterprises of the Volga Federal District and Ural Federal District in 2015-2017 were analyzed. As the information database for analysis of the performance indicators of the enterprises, the official financial reports were used, such as Balance sheet and Income statement over a period of 2015-2017.

The accountancy data of the enterprises were collected using the System of Professional Analysis of Markets and Firms. The construction and analysis of the sustainability assessment model were carried out using the IBM SPSS Statistics package.

Based on the previously analyzed Russian and foreign models, it can be argued that the indicators used in model construction can be arranged into the following groups: liquidity, debt position, solvency, rate of return, and economic efficiency. For the construction of the sustainability assessment model we selected indicators which fully characterize the economic activity of the enterprise in accordance with those groups (Table 2).

In this research, we set the following criteria to determine the sustainability of the development: for enterprises with an unstable economic condition, the coefficients characterizing liquidity, profitability, solvency and efficiency have smaller values than the values of indicators of "sustainable" enterprises. Coefficients characterizing debt or turnover rate should be lower for enterprises that are developing steadily (Savickaya, 2002).

Since we are building a model based on the data of 20 engineering enterprises, the test for normal distribution using the Kolmogorov-Smirnov method is not carried out. Because the sample scope is too small, it is not possible to estimate the normality of the distribution. To compare the average values of the basic indicators of “sustainable” and “unstable” development when variables do not have a normal distribution, a nonparametric Mann–Whitney *U* test is used. The test results are shown in Table 2.

Table 2
The results of nonparametric Mann–Whitney *U* test

Indicator Name	Mann–Whitney U Statistics	Wilcoxon signed-rank test	Z	Asymp. Sig. (2-tailed)	Exact Sig. [2*(1-tailed Sig.)]
Current Ratio	17.000	83.000	-2.469	.014	.012
Cash Ratio	22.000	88.000	-2.100	.036	.038
Ratio of Cash to Revenue	25.000	91.000	-1.861	.063	.067
Ratio of Cash to Total Assets	22.000	88.000	-2.089	.037	.038
Ratio of Working Capital to Revenue	0.000	66.000	-3.761	.000	.000
Ratio of Working Capital to Total Assets	0.000	66.000	-3.761	.000	.000
Asset Turnover Ratio	24.000	90.000	-1.937	.053	.056
Capital Asset Turnover Ratio	21.000	87.000	-2.165	.030	.031
Equity Capital Turnover Ratio	48.000	114.000	-.114	.909	.941
Ratio of Working Assets to Total Assets	27.000	93.000	-1.709	.087	.095
Ratio of Net Income to Capital Assets	22.000	88.000	-2.089	.037	.038
Ratio of Net Income to Total Assets	20.000	86.000	-2.241	.025	.025
Ratio of Short-term and Long-term Liabilities to Total Assets	3.000	48.000	-3.533	.000	.000
Ratio of Current Liabilities to Equity Capital	45.000	90.000	-.342	.732	.766
Ratio of Long-term Liabilities to Total Assets	19.000	64.000	-2.317	.020	.020
Intermediate Liquidity Ratio	14.000	80.000	-2.698	.007	.006
Ratio of Loan Capital to Equity Capital	39.000	84.000	-.798	.425	.456
Financial Stability Index	21.000	87.000	-2.166	.030	.031
Asset Coverage	37.000	103.000	-.950	.342	.370
Current Assets Turnover Ratio	25.000	91.000	-1.861	.063	.067
Net Working Capital Turnover Ratio	7.000	73.000	-3.230	.001	.001

Indicator Name	Mann–Whitney U Statistics	Wilcoxon signed-rank test	Z	Asymp. Sig. (2-tailed)	Exact Sig. [2*(1-tailed Sig.)]
Output Profitability	27.000	93.000	-1.709	.087	.095
Return on Sales	28.000	94.000	-1.633	.102	.112
Return on Property Plant and Equipment	22.000	88.000	-2.089	.037	.038
Return on Assets	20.000	86.000	-2.241	.025	.025
Return on Equity	32.000	98.000	-1.330	.184	.201
Fixed-Asset Turnover	25.500	91.500	-1.824	.068	.067
Capital-Output Ratio	34.500	79.500	-1.141	.254	.261
Inventory Turnover Ratio	35.500	101.500	-1.064	.287	.295
Receivable Turnover	16.000	82.000	-2.545	.011	.010
Grouping variable: Status					

Source: authors

With a significance point of less than 1%, the difference in average values for “sustainable” and unstable enterprises is statistically significant for 5 variables: Ratio of Working Capital to Revenue, Ratio of Working Capital to Total Assets, Ratio of Short-term and Long-term Liabilities to Total Assets, Intermediate Liquidity Ratio and Net Working Capital Turnover Ratio. Average values of indicators such as Current Ratio, Cash Ratio, Ratio of Cash to Total Assets, Capital Asset Turnover Ratio, Ratio of Net Income to Capital Assets, Ratio of Net Income to Total Assets, Ratio of Long-term Liabilities to Total Assets, Financial Stability Index, Return on Property Plant and Equipment, Return on Assets, Fixed-Asset Turnover and Receivable Turnover significantly differ at the point of less than 5%. For other indicators, the difference between the average values is insignificant.

The results suggest that indicators of “sustainable” and “unstable” enterprises which differ significantly can be used to build a model. To check the interrelation of the values of the indicators, Spearman's rank correlation coefficient was used. It showed the presence of the correlation between indicators.

To build a regression model, we divided the sample into 2 parts: “sustainable” and “unstable” enterprises. In this case, the “sustainable” enterprises include the sample of enterprises which, as a result of our research, were characterized as “sustainable” based on 4 out of 7 models described above. Thus, we included 20 enterprises in the training sample, 9 of which were considered “sustainable” in 2016-2017, and 11 of which had gone through an unstable economic conditions.

Logistic regression was chosen as the method for the modelling. As a dependent variable in the model, a dichotomous variable, designed to categorize

the status of the enterprise: 1 - “sustainable”, 0 – “unstable”, was set up. As an independent variable, indicators characterizing the activities of the company divided into 5 groups were used: liquidity, debt position, solvency, rate of return, and economic efficiency, in respect of which the following conditions were met:

1) average values of “sustainable” and “unstable” enterprises differ significantly;

2) the linkage between the other indicators, estimated using the Spearman's rank correlation coefficient, is weak.

These conditions are necessary and sufficient for the following indicators: Ratio of Short-term and Long-term Liabilities to Total Assets, Net Working Capital Turnover Ratio, Cash Ratio, Ratio of Long-term Liabilities to Total Assets, Financial Stability Index, Return on Property Plant and Equipment and Fixed-Asset Turnover.

In modelling the method of step-by-step inclusion of variables was chosen. The results of the model are given in Table 3.

Table 3
Indicators of the static model for assessing economic sustainability of the development of the enterprise

		B	**Standard error**	**Wald**	**df**	**Significance**
Step 1	Ratio of Short-term and Long-term Liabilities to Total Assets	-12.089	5.677	4.535	1	0.033
	Constant	7.885	3.845	4.206	1	0.040

Source: authors

The resulting model has the following form

$$P_j = \frac{1}{(1+e^{-z})} = \frac{1}{1+e^{(-(7{,}885-12{,}089x_{1,j}))}}$$

where P_j is the probability of the «sustainable» development of enterprise *j*, *e* is the exponent function, and $x_{1,j}$ is the ratio of short-term and long-term liabilities to total assets.

If the calculated probability of the sustainable development is less than 0.5, then the enterprise should be classified as "unstable"; if the probability is more than 0.5, then the enterprise can be classified as “sustainable”. The resulting model is a static estimate of the probability of the sustainable development of the enterprise, because it was constructed using the data for the same year as the research occurred and does not take into account the change in economic indicators in retrospective dynamics.

2.3. Dynamic Model

For the timely identification of the direction of the enterprise’s development, the authors have developed a dynamic model that takes into account the retrospective behavior of the indicators.

To develop a dynamic model of the assessment of the economic sustainability of enterprise development, the same sample as in the static model was used: enterprises with “sustainable” development based on 4 out of 7 models, and enterprises that were classified as “unstable”. The dynamic model was developed using logistic regression method. The status of the enterprise was set as a dependent variable: 1 – “sustainable”, 0 – “unstable”. As for independent variables the following indicators were used: sustainability probability of the enterprise in 2016, sustainability probability of the enterprise in 2017, and the ratio of “sustainability probability -2017” to “sustainability probability -2016”. The sustainability of the enterprise was calculated using the static assessment model developed by the authors. Table 4 shows the estimated coefficients for the resulting dynamic model.

Table 4
Indicators of the dynamic model for assessing economic sustainability of the development of the enterprise

		B	Standard error	Wald	df	Significance
Step 1	Sustainability probability - 2016	6.067	2.282	7.070	1	0.008
	Constant	-3.300	1.411	5.470	1	0.019

Source: authors

The resulting dynamic model has the following form

$$P_j = \frac{1}{1 + exp^{(-(-3{,}300+6{,}067P_{jt}))}}$$

where P_{jt} is the probability of the sustainable development of the enterprise *j* in year *t* (in this case, the model includes the probability of 2016).

Thus, in the prediction model of the sustainability of the enterprise's development in the following year, only the probability of the sustainability of the enterprise's development in the previous year is taken into account.

3. Results

The results of the performance of developed models are indicated below.

3.1. Static model results

The performance of the developed model of a static assessment of the sustainable development of enterprises was estimated based on the accuracy of the predicted model. The sample included 11 enterprises with an unstable economic condition, and 9 enterprises recognized as "sustainable" based on 4 models out of 7. The model coefficients were calculated on the basis of reporting instruments in 2016. Table 5 shows the results of applying the constructed model to the sample elements based on which the model was built.

Table 5
Classification of static model results

Observed			Predicted		
			Status		Percentage Correct
			"Unstable"	"Sustainable"	
Step 1	Status	"Unstable"	10	1	90.9
		"Sustainable"	2	7	77.8
	Overall Percentage				85.0

Source: authors

The model correctly predicted "instability" for 10 out of 11 enterprises (90.9% correct answers) and "sustainable development" for 7 out of 9 enterprises (77.8% correct answers). In overall, 85% of enterprises were classified correctly. Thus, the constructed model of static assessment of the sustainability of the enterprise's development showed a high predictive accuracy when testing on this sample.

In addition to the classification table, the quality of the logistic regression model was assessed using one of the indicators of the quality of the fit, log-likelihood. The likelihood measure is the negative double value of the logarithm function (-2LL). The initial value for -2LL is the value that is obtained for the regression model containing only constants. For the model constructed, the initial value is -2LL = 27.526 (Table 6).

Table 6
Iteration history

Iteration		-2 Log Likelihood	Coefficients
			Constant
Step 0	1	27.526	-0.200
	2	27.526	-0.201

Source: authors

For the constructed model with the predictor variable, this value is 9.237, which is a minor value in comparison to the initial value for the model containing only constant (-2LL = 27.526), which indicates a significant improvement of the model performance (Table 7).

Table 7
Model summary

Step	-2 Log Likelihood	Cox & Snell R Square	Nagelkerke R Square
1	9.237	0.599	0.802

Source: authors

The constructed model performance is also characterized by such indicators as Cox and Snell R Square, and Nagelkerke R Square. These indicators are determinacy measures indicating the variance side that can be explained using the logistic regression method. The variance side explained by the logistic regression determined using the Nagelkerke method, is 80.2%, using the Cox and Snell method - 59.9% (Table 7).

To check the null-hypothesis (omnibus tests of model coefficients), chi-squared test is used. In this research, the null-hypothesis can be rejected at 1% significance, which can be confirmed by the data given in Table 8.

Table 8
Omnibus tests of model coefficients

		Chi-square	df	Sig.
Step 1	Step	18.289	1	0.000
	Block	18.289	1	0.000
	Model	18.289	1	0.000

Source: authors

The model performance is also characterized by Hosmer and Lemeshow test. For the constructed model, the value of this criterion is equal to 3.002 with the corresponding significance of 0.934 (Table 9).

Table 9
Hosmer and Lemeshow test

Step	Chi-square	df	Sig.
1	3.002	8	0.934

Source: authors

The results of this test indicate that there is no reason to reject the null-hypothesis of insignificant discrepancies between the constructed model and observations.

Thus, the result of the analysis suggests that the constructed model meets all statistical requirements, and, therefore, can be applied to assess the economic sustainability of enterprise development.

3.2. Dynamic model results

Table 10 shows the results of applying the dynamic model to the sample elements.

Table 10
Classification of dynamic model results

Observed			Predicted		
			Status		Percentage correct
			“Unstable”	“Sustainable”	
Step 1	Status	“Unstable”	10	1	90.9
		“Sustainable”	2	7	77.8
	Overall Percentage				85.0

Source: authors

The dynamic model correctly predicted the sustainable development for 7 out of 9 enterprises (77.8% correct answers) and “instability” for 10 out of 11 enterprises (90.9% correct answers). In overall, 85% of enterprises were classified correctly.

At a significance level of 1%, the null-hypothesis can be rejected (Table 11).

Table 11
Omnibus tests of dynamic model coefficients

		Chi-square	df	Sig.
Step 1	Step	15.010	1	0.000
	Block	15.010	1	0.000
	Model	15.010	1	0.000

Source: authors

The part of the variance explained by the logistic regression, according to the method of Nagelkerke is 70.6%, and according to the method of Cox and Snell, is 52.8% (Table 12).

Table 12
Model summary

Step	-2 Log Likelihood	Cox & Snell R Square	Nagelkerke R Square
1	12.516	0.528	0.706

Source: authors

3.3. Application

The dynamic model developed as a part of the study makes it possible to predict the economic sustainability of the enterprise’s development in the short period of time. Let us make am assessment of the sustainability of the development of enterprises in 2018-2020 using this model. The results are included in Table 13.

Table 13
Assessment of the predicted probability of economic sustainability
of engineering enterprises using a dynamic model in 2018-2020,%

Enterprise	2018	2019	2020
OJSC “Elecond”	92.97	92.88	91.22
PJSC “URAN”	3.85	3.88	4.45
JSC “Arsamassky Priborostroitelny Zavod Imeni Plandina”	32.15	33.28	20.60
OJSC “Bugulma Electric Pump Plant” (BENZ® Runaco Group)	49.35	87.89	42.41
JSC “Hydromash”	89.46	93.48	89.35
JSC “Elecon”	93.45	19.58	91.45
JSC “Drilling and metallurgical equipment plant”	93.99	93.96	91.70
PJSC “Izhevsk plant oil machinery”	82.45	92.60	84.59
JSC “Krasnogvardejskij kranovyj zavod”	93.18	92.27	91.32
JSC “Melinvest”	93.95	94.04	91.68
JSC “OMZ «Gor'kovskij»”	3.56	71.91	4.38
PJSC “PSM-HYDRAULICS”	4.77	4.81	4.70
JSC “TYAZHMASH”	23.52	25.54	13.32
PJSC “Uralmashplant”	3.62	3.62	4.39
PJSC “URAL PLANT OF CHEMICAL MACHINE-BUILDING (URALHIMMASH)”	4.65	4.25	4.66
CJSC “Ahmamet'evskij elektromekhanicheskij zavod»”	90.47	93.17	89.92
PJSC “KAMAZ”	28.07	25.04	16.84
OJSC “Gidroapparat”	3.57	3.56	4.38
PJSC “NPO «Iskra»”	7.95	10.61	5.64
OJSC “Alexandrovsk Machine Building Plant”	4.94	3.80	4.74

Source: authors

The predicted value of the economic sustainability of the development in 2018-2020 is the highest for the following enterprises: OJSC “Elecond”, JSC “Hydromash”, JSC “Elecon”, JSC “Drilling and metallurgical equipment plant”, PJSC “Izhevsk plant oil machinery”, JSC “Krasnogvardejskij kranovyj zavod”, JSC “Melinvest” and CJSC “Ahmamet'evskij elektromekhanicheskij zavod”.

Most of these enterprises also had a sustainable economic condition or were categorized to the “border zone” of sustainability in 2015–2017. The following enterprises run the risk of instability in 2018-2020: PJSC “URAN”, JSC “OMZ «Gor'kovskij»”, PJSC “PSM-HYDRAULICS”, JSC “TYAZHMASH”, PJSC “Uralmashplant”, PJSC “URAL PLANT OF CHEMICAL MACHINE-BUILDING (URALHIMMASH)”, OJSC “Gidroapparat”, PJSC “NPO «Iskra»”, OJSC “Alexandrovsk Machine Building Plant”. Most of these enterprises were recognized as “instable” according to the suggested models in 2015-2017. The developed model allows the authors to hope for the timely implementation of measures to reduce the risk of economic instability for these enterprises in the forecast period.

Thus, this research monitors the sustainability of the development of engineering enterprises of the Volga Federal District and Ural Federal District in 2015-2017. With the help of the sustainability classification, enterprises were divided into 2 groups: “sustainable” and “unstable”. Based on the identified data, the static and dynamic models of the integral estimation of the sustainability of the enterprise’s development using the binary logistic regression method are developed. In the static model the sustainability is influenced by such indicator as Ratio of Short-term and Long-term Liabilities to Total Assets. In the dynamic model the decisive indicator is the probability of the sustainability of the enterprise’s development in the previous year. The accuracy of the developed models allows authors to rely on their further practical application.

4. Conclusions

The sustainable development is the basis for the effective performance of the enterprise, the state and society. First and foremost, the reason for this is the global goal: the natural resource conservation for the future generations and decline of the shattering impact of scientific-technological progress on the environment. It is also important that enterprise performance and development is complicated by permanent effect of environmental factors, often of a negative nature.

There can be a host of factors: the depletion of resources and, as a result, underresourcing of enterprises, the level of social and political tension that affect the economics, world social and economic processes. The successful performance of enterprises within constantly changing external environment requires the implementation of the sustainable development management system, including the economic (strengthening the financial and economic capacity of the enterprise), social (developing human capital) and environmental (rational use of natural resources, environmental impact reduction) component.

For the assessment of the sustainability of the economic system of industrial enterprises, a static model, based on the binary logistic regression method, has been developed. The ratio of short-term and long-term liabilities to total assets is submitted as a predictor in this model. The model allows to determine the probability of the classification of the enterprise as “sustainable” or “unstable”. Thus, the level of the sustainability of the economic system of the enterprise is determined.

For the timely identification of the development direction of the enterprise, the dynamic model which takes into account the nature of the change in indicators in retrospective dynamics has been developed. This model is also based on the binary logistic regression method. The accuracy of the models is 85%. The developed dynamic model allowed predicting the level of the economic sustainability of the researched engineering enterprises until 2020.

The models that the authors have developed are based on financial and economic indicators of 20 engineering enterprises of the Volga Federal District and Ural Federal District in 2015-2017. These models are sui generis to these regions and sectors. The determination of the level of the sustainable development of the enterprise in the shape of a statistically distributed probable (point) characteristics also distinguishes these models from the already-existing ones. Further research can be directed to the development of a model of the complex assessment of the sustainable development of the enterprise, taking into account regional indicators.

The models developed in this research can be exploited by industrial enterprises in their practical activity, which will contribute to increasing the performance improvement, conservancy and maintaining the worldwide trend of the sustainable development.

Bibliographic references

Adams, R. (1999). Performance indicators for sustainable development. *Accounting and Business*, *4*, 37-45.

Altman, E. (1968). Financial ratios, discriminant analysis and the prediction of corporate bankruptcy. *Journal of finance*, *9*, 589–609.

Altman, E. (2005). An emerging market credit scoring system for corporate bonds. *Emerging Markets Review*, *6*, 311–323.

Bagrovnikova, A.N. (2017). Osobennosti issledovaniya ekonomicheskoj sushchnosti ustojchivogo razvitiya promyshlennyh predpriyatij [Research specifics of the economic essence of industrial enterprises' sustainable development]. *Vestnik IzhGTU imeni M.T. Kalashnikova [Bulletin of Kalashnikov ISTU]*, *4*, 69-76. (In Russ.).

Botkin, O.I., Nekrasov, V.I., Botkin, I.O. (2014). Osobennosti issledovaniya ustojchivogo razvitiya organizacii v processah globalizacii [Features of the study on the sustainable development of the enterprise in the processes of globalization]. *Problemy regional'noj ekonomiki [Problems of the regional economics]*, *1-2*, 41-48. (In Russ.).

Evie, F. d', MacDonald, M., Mata, F., Rodriguez, R. (2001). *Earth Council. Guidelines for NCSD Rio +10 assessment*. San Jose: Earth Council.

Fulmer, J., Moon, J., Gavin, T., Erwin, M. (1984). A Bankruptcy Classification Model for Small Firms. *Journal of Commercial Bank Lending*, *66(11)*, 25-37.

Il'in, I.V., Ursul, A.D., Ursul, T.A. (2012). *Global'nyj evolyucionizm: Idei, problemy, gipotezy [Global evolutionism: Ideas, problems, hypotheses].* Moscow: Izdatel'stvo Moskovskogo universiteta. (In Russ.).

Khudyakova, T.A. (2016). Razrabotka integral'nyh pokazatelej ocenki urovnya finansovo-ekonomicheskoj ustojchivosti predpriyatiya [Development of integral indicators for assessing the level of financial and economic sustainability of the enterprise]. *Innovacionnoe razvitie ekonomiki [Innovative development of the economics]*, *6(36)*, 159-164. (In Russ.).

Menzheres, V.N. (2002). *Ustojchivoe funkcionirovanie predpriyatiya v infra-strukture regional'nogo rynka: teoriya i metodologiya [Sustainable functioning of the enterprise in the infrastructure of the regional market: theory and methodology].* St. Petersburg: Izd-vo SPbGUEF. (In Russ.).

Olson, J.A. (1980). Financial Ratios and the Probabilistic Prediction of Bankruptcy. *J. of Accounting Research*, *18 (1)*, 109-138.

Presidential Decree of 1 April 1996 No. 440 *"O Koncepcii perekhoda Rossijskoj Federacii k ustojchivomu razvitiyu" ["On the Concept of the Russian Federation Transition to Sustainable Development"]*. (In Russ.). Retrieved from: http://kremlin.ru/acts/bank/9120

Sajfulin, R.S., Kadykov G.G. (1996). Rejtingovaya ekspress-ocenka finansovogo sostoyaniya predpriyatiya po dannym publichnoj otchetnosti [Rating rapid assessment of the financial condition of the company according to public reporting]. *Finansovye i buhgalterskie konsul'tacii [Financial and accounting consultations], 4*, 24-30. (In Russ.).

Saquet, A-M. (2005). *World Atlas of Sustainable Development: Economic, Social and Environmental Data.* London: Anthem Press.

Savickaya, G.V. (2002). *Analiz hozyajstvennoj deyatel'nosti predpriyatiya [Analysis of the economic performance of an enterprise].* Moscow: INFRA-M. (In Russ.).

Sheremet, A.D. (2006). *Kompleksnyj analiz hozyajstvennoj deyatel'nosti [Complex analysis of the economic activity].* Moscow: INFRA-M. (In Russ.).

Springate, G.L.V. (1978). *Predicting the Possibility of Failure in a Canadian Firm.* M.B.A. Research Project (unpublished). Simon Fraser University. British Columbia.

Stockholm UN Declaration of 16 June 1972. (In Russ.). Retrieved from: http://law.edu.ru/norm/norm.asp?normID=1259490

Taffler, R.J., Tisshaw, H.J. (1977). Going, Going, Gone – Four Factors Which Predict. *Accountancy*, *88,* 50-54.

Ursul, A.D. (2005). Ustojchivoe razvitie: konceptual'naya model' [Sustainable development: a conceptual model]. *Nacional'nye interesy [National interests]*, *1*, 60. (In Russ.).

Ursul, A.D. (2013). Nacional'naya ideya i global'nye processy: bezopasnost', ustojchivoe razvitie, noosferogenez [National idea and global processes: security, sustainable development and noospherogenesis]. *NB: Nacional'naya bezopasnost' [NS: National Security]*, *2*, 1-66. (In Russ.).

Weber, M. (1990). *Izbrannye proizvedeniya [Selected works (trans. and ed. by Yu.N. Davydov)].* Moscow: Progress. (In Russ.).

World Bank. (2003). *World development report 2003 : sustainable development in a dynamic world - transforming institutions, growth, and quality of life*. World Development Report. Washington, DC : World Bank Group. Retrieved from: http://documents.worldbank.org/curated/en/262521468337195361/World-development-report-2003-sustainable-development-in-a-dynamic-world-transforming-institutions-growth-and-quality-of-life

World Commission on Environment and Development. (1989). *Nashe obshchee budushchee: Doklad Mezhdunarodnoj komissii po okruzhayushchej srede i razvitiyu [Our Common Future: Report of the World Commission on Environment and Development Commission].* Moscow: Progress. (In Russ.).

Zhukova, E.A. (2012). Metodika analiza upravleniya ustojchivym razvitiem korporativnyh obrazovanij v usloviyah ciklichnosti [Methodology for analyzing the management of the sustainable development of corporate entities in cyclical conditions]. *InVestRegion [Innovative Bulletin of the region]*, *2*, 15-19. (In Russ.).