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Approaches to Ensuring the Sustainability of Industrial Enterprises of Different Technological Levels

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Abstract

This article is aimed at determining the areas for ensuring the sustainability of development of an industrial enterprise, depending on whether it belongs to the high-tech or low-tech sector. Semantic analysis, correlation-regression analysis, fuzzy logic and real option are used as research tools. The results of the research demonstrate that sustainability of representatives of high-tech industries depends on the specifics of generation and integration of innovations, while for representatives of low-tech industries this factor is of little significance. As a result, two fundamentally different tools are proposed to ensure sustainability of enterprise development. For low-tech industrial enterprises it is a model for predicting the level of sustainability of counterparty development based on a real option, and for high-tech industrial enterprises, it is a model for evaluating the prospects of innovative solutions based on fuzzy logic. The formed tools, if used by industrial enterprises and public institutions, will help to balance the development of industry and, as a result, will allow the country to obtain stable competitive positions in the global economy.

Keywords: Low-tech industry; High-tech industry; Sustainable development; Economic growth; Financial condition; Bankruptcy; Qualitative change; Fuzzy set theory; Real option.

1. Introduction

Despite the fact that the manufacturing industry occupies a system-forming place in the economy of many countries, global trends suggest its ambiguous development. If we analyze the dynamics of gross world product by the main sectors (agriculture, manufacturing industry, services) (UNCTAD), it becomes obvious that from 1970 to 2000, the service sector grew faster than the manufacturing industry (up to 4.5% per year), but since 2000, the annual growth of all three sectors has equalized and stabilized at about 2.5%. The dynamics of industrial development in the world's largest groups of countries also varies. Since 1960s (for developing countries - 1980s, for the countries of the former USSR –1990s), the world manufacturing industry has taken a course towards de-industrialization. On a global scale, the share of value added of the manufacturing industry in GDP in the period from 1962 to 2012 dropped from 20.9% to 12.3% (Lavora and Szizmai, 2015). In Western Europe, the USA, Canada, Japan, Singapore, Australia, and New Zealand, the share of value added of the manufacturing industry in GDP is steadily declining according to the global trend. For the countries of the former USSR and East Asia, the share of value added of the manufacturing industry in GDP either grows or the periods of recession and growth change each other (Sharafanova *et al.*, 2017; Skhvediani *et al.*, 2017).

Thus, it is quite obvious that the manufacturing industry plays different roles in the national economy of developed and developing countries. The consequence is that competition in the manufacturing industry is growing. At the same time, this effect is felt primarily in high-tech and low-tech industries. If we consider the percentage of different sectors of the manufacturing industry in the technological structure of world exports in 1990 and 2013 (Industrial development report, 2016), the growth rates of low-, medium- and high-tech sectors of the economy almost halved over the recent years, with a 50% prevalence of the medium-tech sector in absolute terms. Consequently, for low- and high-tech industrial enterprises, the issue of sustainability of enterprise development (SED) is becoming much more important.

Within this study, the authors consider the features of ensuring the sustainability of development of low- and high-tech industrial enterprises. The *primary hypothesis* is: approaches to ensuring the sustainability of development of low- and high-tech industrial enterprises are fundamentally different. Based on this primary hypothesis, the following *aim of the research* was formulated: to develop applied tools for ensuring the sustainability of development of an industrial enterprise at a strategic level. They must be differentiated depending on the technological level.

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2. Literature Overview

World science does not declare a single approach to defining the concept of "sustainability of development". Many well-known researchers interpret this term in the same way as the notion of "sustainable development". Scientists from the countries of the former Soviet Union region and East Asia separate these concepts. "Sustainability of development" can be interpreted as the ability of a system to change providing an increase in the potential, under the influence of destabilizing factors of the external environment. The term "sustainable development" has become widely spread after the World Commission on Environment and Development published the report "Our Common Future", which drew attention to the problem of "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Report of the International Commission on Environment and Development, 1987).

As for "sustainability of enterprise development", the authors agree with the opinion of Zinger and Ilyasova, according to which "sustainability of enterprise development" means that an enterprise operates to its best advantage, which is expressed by its existing and potential capabilities to resist destabilizing externalities and internalities in a certain time space, and at the same time to maintain and increase its potential and positive direction of development (Zinger and V., 2015). Works by many researchers contain similar interpretations (Ermolenko and Merzlikina, 2008). We can conclude that "sustainability of enterprise development" is a more local phenomenon, in contrast to "sustainable development of an enterprise." In this case, it is not meant to ensure sustainable development of the global system but to implement qualitative and quantitative changes, the purpose of which is to increase the capacity of an organization to withstand destabilizing externalities.

The range of tools for assessing the sustainability of enterprise development is primarily based on tools that are used to assess the financial condition of an enterprise. In modern practice there are quite a few tools like that. Many of them are methods for diagnosing the threat of bankruptcy. The following models are some of the best-known foreign methods of assessment: the five-factor model of E. Altman (1968); the nine-factor model of J. Fulmer (1984); the Conan – Holder five-factor model (1979); the four-factor model of R. Lis (1972); the four-factor model of R. Taffler and G. Tisshaw (1977); The three-factor model of J. Legault; The four-factor model of G. Springate (1978). Researchers from the countries of the former Soviet Union also studied the issues of assessing bankruptcy threat of a company: the four-factor model of G.V. Davydova and A.Yu. Belikov; the six-factor model of O.P. Zaitseva; The five-factor model of A.D. Sheremet and R.S. Sayfullin; the five-factor model of V.V. Kovalev and O.N. Volkova; the five-factor model of G.V. Savitskaya; the model of V.I. Barilenko, S.I.Kuznetsov, L.K. Plotnikova & O.V. Cairo.

All the mentioned models converge in one: a certain qualitative change becomes the driver of development and changes in the financial condition of an enterprise. Many researchers have investigated this issue as applied to industrial enterprises and singled out the process of integrating new production technologies (additive technologies, computer engineering, etc.) as key qualitative changes that ensure the sustainability of development of an industrial enterprise (Gebler *et al.*, 2014; Mellor *et al.*, 2014). Other researchers see the process of integrating new materials as a source of qualitative changes (Slyusar, 2009), and as the processes of creating new consumer values (Garetti and Taisch, 2012; Leiserowitz, 2006; Thogersen, 2004).

The described scenarios (see Table 1) show the areas of qualitative changes that can ensure the development of an industrial enterprise. However, it is about the possibility of applying these scenarios where the key difference between the sustainability of development of low-tech and high-tech industrial enterprises lies.

Table-1. Scenarios for The Implementation of Qualitative Changes

#	Directions	Description of scenarios
1.	New production technologies =1 New materials =1 New consumer values =1	
2.	New production technologies =-1 New materials =1 New consumer values =1	
3.	New production technologies =-1 New materials =1 New consumer values =-1	
4.	New production technologies =1 New materials =1 New consumer values =-1	
5.	New production technologies =1 New materials =-1 New consumer values =1	
6.	New production technologies =-1 New materials =-1 New consumer values =1	
7.	New production technologies =1 New materials =-1 New consumer values =-1	
8.	New production technologies =-1 New materials =-1 New consumer values =-1	

According to the Organization for Economic Co-operation and Development (OECD) (ISIC REV. 3 Technology intensity definition, 2011), the share of R&D costs in low-tech industries is less than 1.5%. This fact means that qualitative changes cannot be made in accordance with the selected scenarios, because of the extreme budget insufficiency. Therefore, scenario #8 is the key development scenario for low-tech enterprises. In this case, an exceptional role is played by the enterprise's ability to predict possible unfavorable changes in the external environment, and respond to them in due time. Consequently, projection tools will be the key tools for ensuring the sustainability of development.

In the case of high-tech industries, the situation is exactly the opposite. The increment of the development potential of representatives of these industries relies on generating innovations and their integration into the production process (Gkypali and Tsekouras, 2015). The development of these enterprises can be based on one of the first 7 scenarios described above. Therefore, one of the most relevant tools for ensuring sustainability of development in this case will be a tool assessing the level of prospects for possible qualitative changes.

The literature review allows us to formulate the following *hypothesis*: timely reaction to the influence of the external environment, which does not imply qualitative changes in the production process, is a source of the sustainability of development for low-tech industrial enterprises, while advanced innovative solutions entailing qualitative changes is the source of the sustainability of development for high-tech industrial enterprises.

3. Data and Applied Methods

3.1. Low-tech Industry Research

The authors identified above 13 of the most common models for assessing bankruptcy threat. Since none of these models considers the characteristics of the external environment, or uses any specialized projection methods, the scenarios for the development of an enterprise are constructed by extrapolation. It is assumed that an unsatisfactory level of financial stability in the current period, under persistent conditions of the external and internal environment, will lead to financial failure of the enterprise in the subsequent period. The final indicator of any projection model that allows us to make a conclusion about its practical value and applicability in real conditions is its ability to make correct projections. Consequently, the effectiveness of the model is determined by assessing posterior values of bankruptcy risk, or compliance with the criteria for sustainability, for various periods of projection. Within this study, periods of 1, 2, 3, 4 and 5 years after the final date of the analyzed period (calendar year) have been selected. The sample of the study consists of 20 bankrupt enterprises and 10 financially successful enterprises. Homogeneity of the sample is ensured by the fact that all selected enterprises are manufacturers of dairy products. In the case of financially sustainable enterprises, financial statements from 2011 to 2015 are considered. The study of these models will help us to reveal effective indicators predicting the loss of financial stability.

3.2. High-tech Industry Research

Building a tool to assess the potential for qualitative change is a non-trivial task. Within this study, we understand potential as the investment attractiveness of qualitative changes (Kudryavtseva *et al*., 2017). However, the planning horizon is much farther, and the resulting indicators can include not only profit and profitability of sales, but also market share, the dynamics of return on sales, labor productivity, and the dispersion of financial stability indicators in the long run. Qualitative changes are specific as an object, which does not make it possible to use any of the common statistical or expert evaluation methods in their pure form (Melnikov *et al*., 2016; Niyazova *et al*., 2016). The accuracy of the assessment results can be increased through the use of methods based on the fuzzy set theory. A.O. Nedosekin was the first to apply the theory of fuzzy sets for describing economic processes (Nedosekin, 2003). He suggested an algorithm for evaluating a complex economic indicator using the theory of fuzzy sets. The authors believe that the principles of the fuzzy set theory are universal. So a model for estimating the index of qualitative changes potential is formed on its basis.

4. Research Results

4.1. Results of low-Tech Industry Research

In accordance with the financial statements of the sample the resultant indicators of each of the 13 models have been calculated over the period of 5 years. In this case the resulting indicators are not only indicators of the financial stability level, but also indices of either bankruptcy threat, or financial stability preservation. After 13 best-known models were analyzed, it has been found out that none of them is effective enough to predict the sustainability of development. The efficiency level of models can be represented quantitatively as half of the sum of the predictive "strength" of the model with a projection period of 1 year, and the unit difference and modulus of the share difference of correctly classified cases. The results can be presented as a score. According to the formed ranking, the most effective model is the model of Zaitseva and the model of Altman. However, the maximum value of the efficiency index is 61 points. This means that results obtained by the model Zaitseva are true with 61% probability.

The results of the analysis demonstrate the need to develop a new methodology for assessing the financial stability of an industrial enterprise. The existing models were disaggregated into separate indicators. The subsequent study of the predictive strength of each of the indicators helped to form the following evaluation system: 1. Assessing the level of enterprise business activity estimated as the asset turnover ratio (X_1); 2. Assessing the level of solvency of the enterprise estimated as the current liquidity ratio (X_2); 3. Assessing the financial independence of the enterprise estimated as equity to debt capital ratio (X_3). Regulatory values of these coefficients may vary depending on the industry. At the same time, current indicators cannot be used to assess the sustainability of development, since they are moment-specific. For the transition to assessing the sustainability of development, it is necessary to project the change in these indicators based on the characteristics of the external environment. Since an enterprise is supposed to adapt to changes of the external environment, the future can be regarded as a set of alternatives that can positively or negatively affect the sustainability of an enterprise. Therefore, an enterprise can be considered as a real option. Based on the model for estimating the future price of the Black-Scholes option (Black and Scholes, 1973), the following model has been developed for predicting the values of the selected indicators (Formula 1).

$$C = \frac{SN(d_1)}{Ee^{-rN(d_2)}}$$

$$d_1 = \frac{\ln\frac{S}{E} + \left(r + \frac{\partial^2}{2}\right)}{\partial} \quad (1)$$

$$d_2 = d_1 - \partial$$

where C is the projected value of the indicator; S is the numerator of the ratio (revenue, equity capital, current assets); E is the denominator of the fraction (total assets, short-term liabilities, debt capital); r is the rate of return; ∂ is the average magnitude of indicator fluctuations; N (d) is the cumulative standard normal distribution of probabilities; d_1 *and* d_2 *are the standardized normal variables.*

The study of this model effectiveness indicates its statistical significance. The predictive power of this model with respect to the current liquidity indicator is 87%, in terms of asset turnover - 72%, and with respect to the ratio of equity and debt capital - 75%. Since industry normative values can be established for each indicator, a possible set of relations between their current and future values has a finite value if these relations are considered without identifying quantitative changes. Consequently, the system of sustainable development of a low-tech industrial enterprise can be represented in the form of 64 possible conditions, with each of them characterized by the dynamics of changes in key indicators of sustainability. For each of the 64 states, a system of recommendations has been drawn up to point out specific measures to improve the sustainability of development. The obtained algorithm enables the enterprise to adapt to the changing environmental conditions in due time.

4.2. Results of High-tech Industry Research

Literature overview allows us to determine the key indicators of assessment (Table 2).

Table-2. System of Indicators for Evaluating the Potential of Qualitative Changes

#	First level indicators	Second level indicators
1.	Implementation risk level (X)	Technological imperfection of the proposed solution (X_1)
2.		The average price dynamics of the final solution elements (X_2)
4.		The cost of additional labor (X_3)
5.		The cost of R & D (X_4)
6.		Time for R&D (X_5)
7.		Payback period (X_6)
8.	Potential rate of return (Y)	The growth rate of the market for technology, material or consumer value (Y_1)
9.		The market capacity of technology, material or consumer value (Y_2)
10.		The versatility degree of the final solution in relation to core production (Y_3)

The generated model has 2 linguistic variables: the index of qualitative change potential and the level of each particular private indicator (9 indicators in total). The term set of each linguistic variable consists of 5 subsets (very low, low, mean, high, and very high). The weights of the second-level indicators are distributed equably. However, it was decided to differentiate the weights between the first-level indicators, depending on the ratio of the cost of implementing a quality solution (P) and the average annual budget of the enterprise for research and development (B). This dependence is linear. If the ratio is equal to one, the weight between the groups is distributed equably. For indicators X_1 - X_6 it is 8.3%, and for indicators Y_1 - Y_3 it is 16.7%. As this ratio increases, the risk indicator grows, and is documented upon reaching 90%. For the indicator of potential rate of return, the reverse dynamics is true.

The standard five-level 01-classifier developed by Nedosekin (2003) is used as a classifier of the index of the qualitative solution potential. This classifier has 5 node points, in which the value of the membership function is equal to one (0.1, 0.3, 0.5, 0.7, 0.9). For each of the indicators, the classifier of current values is generated. These classifiers are built on the basis of statistical information by industry, and the distribution criterion is the frequency of the hit of the indicator value in the interval. Based on the results of calculation of each indicator, their values are recognized by the criterion λij ∈ [0; 1]. This indicator correlates the values of private indicators with the values of the 01-carrier:

$$\lambda_{iJ} = 1 - \frac{X_i - a_3^*}{a_4^* - a_3^*}$$

where a_3^* *and* a_4^* *are the T-numbers of the i-th subset of the term-set.*

Based on the results of recognition of values of private indicators, the index of qualitative change appeal (I) is calculated:

$$I = \sum_{J=1}^{5} p_j \sum_{i=1}^{n=9} r_i \times \lambda_{iJ}$$

where pj are nodal points of the 01-carrier.

In the end, we get an interpretation of the index of qualitative change appeal and the degree of the researcher's confidence in this interpretation.

5. Discussion

The obtained results confirm the hypothesis. The research carried out in relation to the low-tech industry allows us to conclude that the sustainability of development of a low-tech industrial enterprise is primarily manifested in the dynamics of financial stability indicators. The evaluation of the effectiveness of the existing models for bankruptcy risk assessment has proven that at the moment none of them is effective enough. The authors' model has significantly higher predictive capacity. Moreover, the hypothesis about the optional nature of the sustainability of development of a low-tech industrial enterprise has also been confirmed. The resulting algorithm is an applied tool not only for assessing the sustainability of enterprise development, but also for formulating recommendations on its improvement. Consequently, low-tech industrial enterprises are able to ensure the sustainability of their development without introducing qualitative changes in the production process, which require significant investment.

The study conducted for the high-tech industry also produced positive results. The use of fuzzy tools for constructing a model to estimate the index of prospects for qualitative changes made it possible to aggregate the experience of many researchers, and include not only statistical indicators, but also expert ones in the model. Its practical importance is quite high due to its flexibility, and the ability to be applied to almost any project to modernize the production process.

6. Conclusion

The aim of the study was to develop applied tools to estimate the sustainability of development of an industrial enterprise, differentiated depending on its technological level. The obtained tools can be applied to representatives of low-tech and high-tech industries. The hypothesis was confirmed to a full extent that the sustainability of development of a low-tech enterprise can be ensured primarily due to a fast reaction to changes in the external environment, rather than large-scale investments in modernization of the production process. Further research should be devoted to testing and improving the created tools. Moreover, this study does not cover medium-tech industries, which also have their own specifics.

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