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SCENARIO FORECASTING OF ENTERPRISE DEVELOPMENT UNDER CONDITIONS OF UNCERTAINTY

Abstract. *Today's institutional environment for large, medium-sized and small enterprises is dynamic and difficult to predict. The global crisis caused by fundamental changes in the business environment and financial markets has caused a structural breakdown in the logic of doing business, putting on the agenda the problem of choosing the most efficient way for companies to develop with the least expenditure of resources. Scenario forecasting can help managers to make the right decisions and thus reduce the negative impact of the external environment on the business.*

The information basis for our study was the results of the development of large, medium, small and micro-enterprises in Ukraine for the years 2011–2021. In order to implement scenario prediction, we used methods of mathematical modelling and forecasting, based on the study of the performance of economic systems over a certain retrospective period. Using the Farrar-Glober algorithm, we tested the multicollinearity or interdependence between the indicators. The forecasting of the development of enterprises under conditions of uncertainty is proposed to be carried out according to three scenarios.

Consequently, the implementation of the modelling logic has shown that for both entrepreneurship as a whole and for its individual types, the first scenario with a 10% increase in labour costs, while the amount of non-current assets remains unchanged, has the greatest effect. The highest rate of growth in the volume of output sold is provided by all scenarios considered for medium-sized enterprises, slightly less for large enterprises and the lowest for small and micro-enterprises.

The proposed scenario forecasting of enterprise development under uncertainty is easy enough to use and does not require a significant amount of labour or financial resources, which is especially important in the context of any business entity's desire to conserve resources. The value of our proposed modelling is in the fact that using the obtained equations of multiple linear regression, it is possible to estimate other possible scenarios of enterprise development and select the best one among them.

Keywords: *scenario forecasting, entrepreneurship, sold products, remuneration of labour, current and non-current assets, market, crisis*



1. Introduction

Domestic enterprises, regardless of their form of ownership, are constantly influenced by the external environment, which can affect their development in various ways. Market demands dictate the need to monitor current business activity to reduce risk, introduce innovations and strengthen innovative activity. Sometimes business owners do not have enough resources (material, informational or labour) to engage analysts to determine how to move forward. That is why there is a need to develop a methodology for forecasting the development of enterprises in conditions of uncertainty that meets the needs of modern business. The usage of scenario forecasting is the most appropriate in this case. With its help, it is possible to envisage different trajectories of business development and choose the best and most profitable scenario for a particular enterprise. The purpose of this article is to forecast the development of enterprises under conditions of uncertainty using a scenario approach.

In-depth research on enterprise and business development has been carried out in the scientific works of Engel *et al.*, [1], Weerawardena and Mort, [2], Giones and Brem, [3], Dodd, [4], who proposed innovative directions for modelling the activities of business entities. The authors have rightly emphasized the dynamism of the innovation process, the uncertainty of market conditions, the importance of social entrepreneurship development, the need for technological developments, and the adaptation of business culture to global transformation. At the same time, the above scholars proposed modelling tools for the study of business entities under conditions of uncertainty, crises and bifurcations. Haynie *et al.*, [5], developed a framework for “entrepreneurial thinking”, which will allow businesses to sense, act and mobilise under uncertain conditions. This research is more of a psychological science, but it is the right psychological mind-set of the manager and the comfort of the team can guarantee increased profitability of the enterprise. McGrath *et al.*, [6], identify that for the effective development of enterprises, it is necessary to adapt the entrepreneurial culture to support the population and human values. Snihur *et al.*, [7], highlight the need for business model development in technology firms and especially in the aerospace industry. This study is quite relevant as the technologisation of the market economy and industry is key to the competitiveness of both the macroeconomic development of the country and the entrepreneurial units. Gregori and Holzmann, [8], have conducted a similar scientific study, in which they focus on the prospects of business technology development and digitalisation. Important for our study is the research article by O’Brien and Meadows [9], where the authors proposed scenario strategy and technology planning of tools. The article extensively identifies the stages of a scenario to support business

development, development and usage of innovative methods and technologies in knowledge economy conditions. De Brentani, [10], rightly focuses on the fact that managers in a complex external environment have to make complex decisions in a specific situation mode. Consequently, knowledge of the types of different situations or business scenarios that typically lead to success and failure is an important prerequisite for managerial decision-making. The researcher proposed five new service business development scenarios (three of which are related to success and two to failure) adapted to industrial service enterprises. In the conclusions, the scholar suggested a combination of factors that would lead to success under different conditions. The findings of Solodovnik *et al.*, [11], are important for our study. An interesting approach is to investigate the mutual influence of two essential factors for promoting economic development, such as innovation and foreign economic activity, which can be used for scenario forecasting. In particular, this applies to the algorithms for selecting directions of innovative development and methodology for determining the quality of planning work of the Department of foreign economic activity. Flores *et al.*, [12], focused attention on various management factors of microenterprises that influence management decisions. Researchers identified factors for constructing microenterprise management scenarios with emphasis on permanence, corporate social responsibility, knowledge management and microenterprise development. Scenario modelling was used in the work of Jbkare *et al.*, [13], where the potential impact of the COVID-19 pandemic on the tourism industry was measured. Using panel vector autoregression of data from 1995 to 2019 in 185 countries, the authors performed systematic dynamic modelling of the impact of a pandemic crisis on tourism industries worldwide. Noteworthy works on scenario modelling are Picanzo-Castro *et al.*, [14], Cloete *et al.*, [15], Voinea *et al.*, [16], Kushnirenko *et al.*, [17], Bochulia and Sivitska, [18], Bui and Zenchenko, [19], Varnalii *et al.*, [20], Zahra, [21], etc.

The works of scientists show that scenario forecasting at both macro- and meso-, and micro-levels is a highly relevant phenomenon, especially in conditions of uncertainty and crisis situations. Taking into account the tools, methods and models developed by the authors, we will propose our own logic of scenario forecasting of enterprise development in conditions of uncertainty.

2. Materials and Methods

It is important for management decisions to be able to make a scientifically sound assessment of their expected consequences. For such an assessment, forecasting methods based on the study of the performance of economic systems over a certain retrospective period are used. One of such methods is factor forecasting based on multiple regression

equations, reflecting the dependence of performance on the main factors affecting it. A multiple regression equation has the form:

$$Y = f(X_1, X_2, \dots, X_n)$$

where Y is the indicator reflecting the output of the economic system and X_i are the indicators reflecting the factors influencing this output.

Let us investigate the dependence of the performance of business entities in Ukraine on the amount of fixed assets, the amount of current assets and labour costs. For the study, we use a multiple linear regression equation:

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3$$

where Y is the volume of products sold, X_1 is labour costs, X_2 is the amount of current assets, X_3 is the amount of non-current assets.

The information base of the study is the data on the value of these indicators during 2011–2021. The value of the indicator X_i in the t year of this period is denoted by x_{it} .

Before using a multiple linear regression equation, make sure that there is no multicollinearity, i.e. the relationship between indicators X_1 , X_2 and X_3 . If multicollinearity is present, the regression equation cannot be used for forecasting. To check the presence of multicollinearity we use the Farrar-Glober algorithm. To do so, normalize the value of x_{it} of the indicators X_i , using the formula:

$$q_{it} = \frac{x_{it} - \bar{x}_i}{\sigma_{xi} \sqrt{n-1}}, (t = \overline{1, n}), (i = \overline{1, 3}),$$

where q_{it} is the normalised value of indicator X_i in year t of the retrospective period;

n is the length of the retrospective period ($n = 11$);

$\bar{x}_i$ is the empirical mean value of indicator X_i ;

σ_{xi} is the empirical standard deviation of indicator X_i ;

The normalised values of the X_i indicators are shown in Table 1.

Let us denote by $Q^n = (q_{it})$ the matrix, the rows of which correspond to the years of the retrospective period, the columns to the indicators X_i , and the elements are the normalised values of q_{it} of these indicators. We denote by Q^{nT} the matrix transposed to Q^n . We define the correlation matrix $Kor = Q^{nT}Q^n$. It looks like this:

$$Kor = \begin{pmatrix} 1 & 0,97592 & 0,89764 \\ 0,97592 & 1 & 0,84563 \\ 0,89764 & 0,84563 & 1 \end{pmatrix}.$$

To check whether there is multicollinearity between the variables X_1 , X_2 and X_3 we determine the actual and critical value of the criterion χ^2 . The actual value is determined by the formula:

$$\chi^2_{actual} = \left[n - 1 - \frac{1}{6}(2m + 5) \right] \ln(\det[Kor])$$

where n is the duration of the retrospective period ($n = 11$), m is the number of variables ($m = 3$), $\det[Kor]$ is the determinant of the matrix Kor .

We will get $\chi^2_{actual} = -39,112869$. The critical value is determined by the 0.95 confidence probability and the number of degrees of freedom $\frac{1}{2}m(m-1) = 3$. This value is 7.814728. Since the actual value of the criterion by modulo exceeds the table value, there is multicollinearity between the factors. Therefore, you should leave two factors in the regression equation. Determine which factor should be excluded from the model. To do this, let us define matrix W inverted to matrix Kor . This matrix has the form:

$$W = \begin{pmatrix} 34,25234 & -26,07016 & -8,70053 \\ -26,07016 & 23,35240 & 3,65411 \\ -8,70053 & 3,65411 & 5,71990 \end{pmatrix}$$

Then we define a matrix G , the elements g_{jr} of which are determined from the equality:

$$g_{jr} = \frac{-w_{jr}}{\sqrt{w_{jj}w_{rr}}}$$

Table 1

Normalised values of the X_i indicators

Years	Labour costs	Current assets	Non-current assets
2011	-0,34252	-0,31790	-0,45954
2012	-0,27467	-0,26198	-0,44134
2013	-0,24584	-0,20005	-0,37333
2014	-0,25988	-0,19538	-0,10199
2015	-0,24585	-0,21954	-0,07790
2016	-0,12300	-0,16972	0,02142
2017	0,00807	-0,07524	0,21898
2018	0,18565	0,08740	0,20450
2019	0,37097	0,27469	0,27979
2020	0,43339	0,48584	0,32196
2021	0,49367	0,59188	0,40747

Source: calculated by the authors

where w_{jr} denotes the element of the matrix W placed in the j row and r column. This matrix has the form:

$$G = \begin{pmatrix} -1 & 0,92179 & 0,62159 \\ 0,92179 & -1 & -0,01501 \\ 0,62159 & -0,01501 & -1 \end{pmatrix}$$

Based on matrix G , we create a matrix T , the elements t_{jr} of which are calculated using the formula:

$$t_{jr} = \frac{g_{jr} \sqrt{n-m-1}}{\sqrt{1-g_{jr}^2}}.$$

This matrix has the form:

$$T = \begin{pmatrix} N & 6,290756 & 2,099445 \\ 6,290756 & N & -0,88174 \\ 2,099445 & -0,88174 & N \end{pmatrix}$$

The elements of the main diagonal of this matrix are undefined because division by 0 is not possible. The maximum of the remaining elements is $t_{12} = 6,290756$. Let us compare it with the critical value of the Student's criterion, which corresponds to confidence probability 0.95 and the number of degrees of freedom $n-m-1 = 7$. This critical value is 2.3646. Since the element t_{12} exceeds the critical value of Student's criterion, one of the indicators X_1 or X_2 , i.e. labour costs or the volume of current assets, should be excluded from the model. Thus, two models are possible to estimate future output depending on the factors affecting it: a model that determines the dependence of output on labour costs and non-current assets and a model that determines the dependence of output on non-current assets and current assets.

3. Results and Discussion

In scenario forecasting of enterprise development under conditions of uncertainty, it should be taken into account that as long as there is a close correlation between the indicators of current and non-current assets (the correlation coefficient is 0.9875), it is appropriate to choose a model that includes factors of labour costs and non-current assets, i.e. it is determined by regression equation:

$$Y = a_0 + a_1 X_1 + a_3 X_3.$$

Let us introduce an additional variable X_0 , taking the value 1 for all years of the retrospective period, i.e. $x_{0t} = 1$ for all values of t . Then the regression equation can be written as:

$$Y = a_0 X_0 + a_1 X_1 + a_3 X_3.$$

Let us denote by a vector-column A , the elements of which are the coefficients a_0 , a_1 and a_3 . This vector can be defined from the equality:

$$A = (X^T X)^{-1} X^T P$$

where the matrices X and P are of the form:

$$X = \begin{pmatrix} x_{01} & x_{02} & x_{03} & \dots & x_{0n} \\ x_{1n} & x_{1n} & x_{1n} & \dots & x_{1n} \\ x_{3n} & x_{3n} & x_{3n} & \dots & x_{3n} \end{pmatrix}, \quad P = \begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ \dots \\ y_n \end{pmatrix},$$

and X^T is a transposable matrix to matrix X .

By doing the calculations, we get:

$$A = \begin{pmatrix} 1400520756 \\ 10,64426 \\ 0,28486 \end{pmatrix}.$$

Consequently, the linear regression equation is as follows:

$$Y = 1400520756 + 10,64426 X_1 + 0,28486 X_2.$$

Check the adequacy of the resulting equation to the raw data. For this purpose, we determine the coefficient of determination R^2 :

$$R^2 = 1 - \frac{\sum_{t=1}^{11} (y_t - a_0 - a_1 x_{1t} - a_3 x_{3t})^2}{\sum_{t=1}^{11} (y_t - \bar{Y})^2} = 0,96749.$$

With $\bar{Y}$ denotes the mean value of Y indicator for the retrospective period. We then determine the actual value of the Fisher criterion:

$$F = \frac{R^2}{1-R^2} \frac{n-m-1}{m} = 119,037.$$

The resulting value exceeds the critical value of this criterion, which for a confidence level of 0.95 being 4.459. Thus, the regression equation is adequate.

Check the significance of the coefficients a_1 and a_3 of the regression equation. For this purpose, let us determine the t -statistics of these coefficients equal to the moduli of values of these coefficients divided by the standard deviations of their estimates. For coefficient a_1 standard deviation of its estimate is 1.334 and t -statistics 7.9779, for coefficient a_3 the mentioned values are 0.1479 and 1.9256 respectively. Comparing the value of t -statistics with a critical value of the Student's criterion, which at confidence probability 0.9 is 1.8595, we see that the t -statistics for the given coefficients exceed the critical value of criterion. Therefore, the coefficients a_1 and a_3 of the regression equation are significant. This means that the regression equation $Y = 1400520756 + 10,64426 X_1 + 0,28486 X_2$ can be used to determine the expected values of sales under possible changes in labour costs and non-current assets volumes.

Let the planned labour costs be δ_1 , and the planned value of non-current assets is δ_3 . Then the projected volume of products sold is determined by the following equation:

$$\gamma = 1400520756 + 10,64426 \delta_1 + 0,28486 \delta_3$$

Consider three possible scenarios for the development of entrepreneurship:

1) Labour costs increase by 10% compared to 2021, while non-current assets volume remains unchanged.

2) Labour costs remain unchanged, while non-current assets volume increase by 10% compared to 2021.

3) Labour costs and the volume of non-current assets increase by 5% compared to 2021.

Table 2

Forecasting sales volume under different entrepreneurship development scenarios

Change in labour costs compared to 2021	Change in the volume of non-current assets compared to 2021	Forecasted value of sales volume	The growth rate of the volume of products sold compared to 2021
Grow by 10 per cent	Does not change	12514428298	13,1%
Does not change	Grow by 10 per cent	11792970641	6,6%
Grow by 5 per cent	Grow by 5 per cent	12153699470	9,9%

Source: calculated by the authors

For each scenario, we determine the forecast value of the sales volume. The results are shown in Table 2.

A similar study was conducted separately for large, medium, small and micro enterprises. It was found that for all types of enterprises, there is a multicollinearity between the indicators of labour costs, the volume of non-current assets and the volume of current assets. A model based on a linear regression equation that includes two factors — labour costs (X1) and the value of non-current assets (X3)

was developed for each type of enterprise. The resulting regression equations are presented in Table 3.

All equations obtained are adequate and their coefficients at X_1 and X_3 are significant.

Let us consider the three above-mentioned possible business development scenarios and apply them to large, medium, small and micro enterprises. The resulting forecast values of product sales volumes are presented in Table 4.

Consequently, for both entrepreneurship as a whole and for its individual types, the first

Table 3

Multiple linear regression equation for examining the dependence between products sold on labour costs and non-current assets

Type of enterprise	Multiple linear regression equation
Large	$Y = 611426 + 0,00905X_1 + 0,000202X_3$
Medium	$Y = 711194 + 0,00928X_1 + 0,00028X_3$
Small	$Y = 141368 + 0,012756X_1 + 0,000202X_3$
Micro	$Y = 26418 + 0,0132089X_1 + 0,000163X_3$

Source: calculated by the authors

Table 4

Projection of sales volume under different entrepreneurship development scenarios for different types of enterprises

Change in labour costs compared to 2021	Change in non-current assets volume compared to 2021	Forecasted value of sales volume	The growth rate of sales volume compared to 2021
Large enterprises			
Grow by 10 per cent	Does not change	12514428298	13,3%
Does not change	Grow by 10 per cent	11792970641	7,3%
Grow by 5 per cent	Grow by 5 per cent	12153699470	10,3%
Medium-sized enterprises			
Grow by 10 per cent	Does not change	5043705	15,7%
Does not change	Grow by 10 per cent	4729142	8,5%
Grow by 5 per cent	Grow by 5 per cent	4886424	12,1%
Small enterprises			
Grow by 10 per cent	Does not change	2313859	12,1%
Does not change	Grow by 10 per cent	2163755	4,8%
Grow by 5 per cent	Grow by 5 per cent	2238807	8,5%
Microenterprises			
Grow by 10 per cent	Does not change	790189	12,1%
Does not change	Grow by 10 per cent	741704	5,2%
Grow by 5 per cent	Grow by 5 per cent	765946	8,7%

Source: calculated by the authors

scenario has the greatest effect, assuming a 10% increase in labour costs with the same volume of non-current assets. The highest growth rate is provided by all the scenarios considered for medium-sized enterprises, somewhat lower for large enterprises, and the lowest for small and micro enterprises.

4. Conclusions

A guarantee of making effective managerial decisions is the availability of an analytical tool, the usage of which allows the manager to take into account all business development opportunities. Scenario modelling is such a tool, the usage of which helps and guides the entrepreneur in conditions of uncertainty. The uncertainty of the market environment is based on the fact that different directions of events are possible, which can positively or negatively affect the enterprise. It is the development of

scenarios that makes it possible to analyse the consequences for an enterprise of a single phenomenon or several events, which will change the trend of business development by a different degree of influence. The value of our proposed modelling is in the fact that using the obtained equations of multiple linear regression, it is possible to estimate other possible scenarios of business development and choose the best one among them. Our adapted modelling is simple enough to use and does not require a significant amount of labour or financial resources, which is especially important in the context of any business entity's desire to conserve resources. Our further research will be aimed at expanding the possible scenarios of entrepreneurship development, which is a relevant issue considering the instability and rapid change of the entire institutional matrix of entrepreneurship and the growing competition between countries and businesses at the global level.

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СЦЕНАРНЕ ПРОГНОЗУВАННЯ РОЗВИТКУ ПІДПРИЄМСТВ В УМОВАХ НЕВИЗНАЧЕНОСТІ

Анотація. *Сучасне інституціональне середовище великих, середніх та малих підприємств є динамічним та важко передбачуваним. Загально світова криза, яка викликана докорінною зміною кон'юнктури та фінансових ринків спричинила структурний злам логіки ведення бізнесу, поставивши на порядок денний проблематику вибору найефективніших шляхів розвитку підприємств при мінімальних ресурсовитратах. Сценарне прогнозування спроможне допомогти управлінцям вірно прийняти необхідне рішення та таким чином зменшити негативний вплив зовнішнього середовища на бізнес.*

Інформаційним підґрунтям для нашого дослідження були результати розвитку великих, середніх, малих та мікропідприємств України за 2011–2021 роки. З метою реалізації сценарного передбачення нами були використані методи математичного моделювання та прогнозування, засновані на дослідженні показників діяльності економічних систем протягом певного ретроспективного періоду часу. З використанням алгоритму Фаррара-Глобера нами перевірялася мультиколінеарність або взаємозалежність між показниками. Прогнозування розвитку підприємств в умовах невизначеності запропоновано здійснювати за трьома сценаріями.

Отже, реалізація логіки моделювання показала, що як для підприємництва в цілому, так і для його окремих видів, найбільший ефект має перший сценарій, що передбачає зростання на 10% витрат на оплату праці при незмінній величині необоротних засобів. Найвищий темп приросту обсягу реалізованої продукції забезпечують всі розглянуті сценарії для середніх підприємств, дещо менший для великих і найменший для малих та мікропідприємств.

Запропоноване сценарне прогнозування розвитку підприємств в умовах невизначеності є досить простим у використанні та не вимагає залучення значної кількості трудових або фінансових ресурсів, що особливо важливо в контексті прагнення будь-якого суб'єкту господарської діяльності до ресурсозбереження. Цінність запропонованого нами моделювання полягає у тому, що використовуючи одержані рівняння множинної лінійної регресії можна оцінити і інші можливі сценарії розвитку підприємництва та обрати серед них найкращий.

Ключові слова: *сценарне прогнозування, підприємництво, реалізована продукція, оплата праці, оборотні та необоротні активи, ринок, криза*