Enterprise growth simulation model

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Abstract. Simulation mathematical model of small enterprise functioning is under analysis in this article. It is assumed that annual working capital profitability and loan rate are random variables with normal distribution, the amount of borrowed capital does not exceed the amount of own working capital. Given the value of its working capital at the beginning of time, its dependence on time is constructed as a random process. The parameters of random variables are estimated based on the processing of statistical data on the previous activities of this enterprise. The implementation of the random process is statistically modeled. With the help of the statistical tests, implementations of random function of growth of own working capital are built and the probability of bankruptcy is estimated as relative frequency of cases of adoption of negative value by random function. It is proposed to use the built simulation model of the enterprise to estimate the probability of bankruptcy of the studied enterprise in the coming period (a given number of years).

1 Introduction

For reasonable decision-making in enterprise management, its financial management should be able to assess the consequences of the decisions taken. Therefore, mathematical methods and models of forecasting financial indicators of economic and enterprise economic activity are important.

In [1] a comparative analysis of the use of simulation packages and computer mathematics systems for the analysis of models of economic growth theory was carried out. The results of application of mathematical packages are considered on the example of Matlab (Mathworks) program and iTthink simulation package (isee systems, inc.) for Solow-Sven model analysis. Work [2] is devoted to application of mathematical package of MatLab for numerical-analytical study of problems of theory of economic growth.

A statistical model is a special class of mathematical model. The main difference of statistical model from other mathematical models is that it is nondeterministic. It simulates statistical data. Thus, in a statistical model defined by mathematical equations, some variables have no specific values, but instead have the probability division; that means that some variables are stochastic.

Statistical modeling is the study of objects of knowledge on their statistical models. Statistical models in economics are necessary for the theoretical study of the effects of

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random factors on economic processes. When random processes are taken into account, the movement of the system is no longer subjected to dynamic laws, but it is subjected to the laws of mathematical statistics. Accordingly, questions about the veracity of a given cash flow could be raised, the most likely movements and other probabilistic characteristics of the economic system behavior. The parameters of such models are assessed by using statistical methods [3-8].

In [9-15], various tasks of managing the enterprise's economy are considered.

2 Problem formulation

Let us consider the problem of strategic forecasting of small enterprise development on the basis of analysis of statistical data on financial and economic indicators of its economic activity. Let us assume that the enterprise was in a financial state of normal stability during the previous period and intends to adhere to such financial policy that the amount of borrowed funds does not exceed the amount of its own working capital, and the borrowed funds consist only of the short-term debts. Working capital consists of its own working capital and of short-term arrears. The expected return on working capital is estimated on the basis of statistics on previous activities. The expected loan rate is also estimated on the basis of statistics from previous years. In future activities net profit is expected to be added to the working capital. It is necessary to build a strategic forecast for the next few years of changes in own working capital value.

3 Creation of a simulation model

Let us consider the small business model and build a dependence of own working capital value on OWC (t) time, assuming that at the beginning of time the values of own working capital DC (t) capital at the beginning of time $t = 0$ are known, with working capital WC (t) equal to the sum of the capital Dc (t) of the working capital Wc (t).

At the same time profitability of working capital and cost of borrowed capital (loan rate) are considered random values with normal laws of probability distribution with specified mathematical values and standard deviations. We will build a simulation model of growth of own working capital OWC (t) of the enterprise for this period of time (for example, ten years). For this purpose the pseudo-regional credit rate γ and the return rate p are tested for each time period, taking into account the sample average and standard deviations of profitability and the credit rate, and then calculating the equity value OWC (t) for each period t . Assume that the income tax rate is τ .

The calculation of working capital is based on the following algorithm:

For each $t = 0, 1, \dots, 9$ execute

1) Calculate working capital WC (t) by formula

$$WC(t) = OWC(t) + DC(t) \quad (1)$$

2) Calculate profit before taxes PBT (t) before taxes by formula

$$PBT(t) = WC(t) * p - DC(t) * \gamma \quad (2)$$

Here the rate of return on equity p and the rate of interest are calculated as random values with the normal law of distribution of probabilities. Excel applies the following formulas for this purpose:

$$p = \text{NORMINV}(\text{RAND}(); a_p; s_p) \quad (3)$$

$$\gamma = \text{NORMINV}(\text{RAND}();a_{\gamma};s_{\gamma}) \tag{4}$$

Here a_p, a_{γ} are average values and s_p and s_{γ} are standard differences in profitability rates and credit rates.

If the pre-tax profit PBT (t) is positive, net profit NP (t) is calculated with the tax rate

$$\text{NP}(t) = \text{PBT}(t) \cdot (1 - \tau) \tag{5}$$

At the same time net profit is added to own current capit in the next period

$$\text{OWC}(t + 1) = \text{OWC}(t) + \text{NP}(t) \tag{6}$$

If PBT (t) is negative before taxes, it is added to the net working capital in the next period

$$\text{OWC}(t + 1) = \text{OWC}(t) + \text{PBT}(t) \tag{7}$$

3) Calculate DC 's (t 1) loan capital equal to its own working capital

$$\text{DC}(t + 1) = \text{OWC}(t + 1) \tag{8}$$

Other borrowing strategies are possible, such as using the formula $\text{DC}(t + 1) = \text{OWC}(t + 1) / 2$ instead of formula (8).

As the result of each experiment implementation, the growth of the own working capital OWC (t), which may be a function with positive values, or a function which at some point in time takes a negative value, is obtained. If for $t = t_0, (1 \leq t_0 \leq 10)$ the OWC condition $(t_0) < 0$ will be met, we will assume that bankruptcy has occurred. Figure 1 shows graphs of possible realizations of the OWC function (t). Figure 2 and Table 1 show a demonstration bankruptcy case. For the first and second years we have negative profits and for the second year the working equity was negative. In the strategy used here, the borrowing capital was used in the amount of its own working capital for each period.

Table 1. Bankruptcy case: own working capital turned negative during the second year.

t	OWC (t)	DC(t)	WC (t)	p(t)	$\gamma(t)$	PBT(t)	NP(t)
0	1000.00	1000.00	2000.00				
1	197.80	197.80	395.60	-0.19	0.42	-802.20	0.00
2	-50.42	0.00	-50.42	-0.36	0.53	-248.22	0.00

Fig. 1. Graphs of possible implementations of OWC function (t).

Fig. 2. Bankruptcy case: own working capital turned negative during the second year.

In the favorable case, the random function $OWC(t)$ will be close to the exponential function. Figure 3 shows an example of the implementation of the random function $OWC(t)$ at values: the average expected value of the working capital profitability of the 0.25; standard deviation - 0.08; average credit rate 0.11 at standard deviation 0.02.

In this case, the implementation of the random function $OWC(t)$, the working equity grows by the exponential function

$$OWC(t) = 1131,4 e^{0,2301 t}$$

The degree of reliability of the exponential trend line is 0.98.

Fig. 3. Example of a favorable implementation of a random function.

4 Results of computing experiments

In order to investigate the predictive behavior of a particular enterprise, working capital rents were calculated on the basis of previous years' statistics and their average and standard deviations were estimated. The average and the standard for the loan rate (in annual) were also estimated from the statistical data.

On the basis of these indicators and the income tax rate according to the above algorithm (1) - (8), the growth functions of the own working capital of OWC (t) were calculated and the probability of bankruptcy was estimated as the relative frequency of occurrence of OWC (t0) < 0 (Fig.2). The implementation of the algorithm in Excel was used to obtain the results shown in Table 1 and Figures 1, 2 and 3.

Table 2 shows the bankruptcy probabilities for various profitability rates and loan rates. The results were obtained by implementing simulation model (1) - (8) in Matlab [7, 8] program with number of tests k = 10000 (number of calculations of OWC function (t), where t = 0, 1,..., 10).

Table 2. Estimates of bankruptcy probability using simulated model (1) - (8).

Variants series tests	a_p	s_p	a_γ	s_γ	τ	Expected probability of bankruptcy
1	0.35	0.15	0.12	0.05	0.20	0.20
2	0.25	0.10	0.18	0.05	0.20	0.36
3	0.25	0.15	0.12	0.05	0.20	0.60
4	0.25	0.10	0.12	0.05	0.20	0.22
5	0.20	0.05	0.12	0.05	0.20	0.04
6	0.20	0.1	0.12	0.05	0.20	0.52

5 Conclusion

As a result of analysis of results obtained with the help of computational experiments in MatLab:

The higher the volatility of the working capital profitability indicator, the higher the probability of bankruptcy.

This simulation model of the enterprise development describes the influence of statistical characteristics of the return on the working capital of the enterprise stable growth of its own working enterprise.

Since the development of its own working capital is an important factor in the growth of the enterprise, it could be considered that the proposed simulation model is adequate enough to study the properties of a small or medium-sized enterprise.

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