Methodology for modelling stochastic optimization of innovative development of enterprises using probabilistic methods

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Abstract. The article proposes the results of a scientific study based on the construction of mathematical models of stochastic optimization using probabilistic methods aimed at the innovative development of timber industry enterprises. The construction of economic and mathematical models is a necessary direction when forecasting various processes. The construction of stochastic optimization models based on economic and mathematical modelling makes it possible to establish a number of the most significant cause-effect relationships of technological, resource and effective indicators using formalization parameters, as well as determine the nature of the likely relationship between the indicators. The most relevant from a scientific and practice-oriented point of view for modelling the dynamics of technological and innovative development of an enterprise is the application of probabilistic methods using production functions. When applying production functions, in a scientific approach, many average indicators were used, taking into account various production and technological relationships of the production process, technological solutions and innovations. Based on the methodology of stochastic optimization in the construction of production functions in the process of economic and mathematical modelling, it is possible to form an adequate production function to build the necessary mathematical model and forecast scenarios of the dynamics of innovative development of enterprises.

1. Introduction

The study pays attention to the influence of the factors of random variability of the production and technological function of innovative development of enterprises on the results of modelling of stochastic optimization, and the possibility of using probabilistic methods in computer analysis of data [1].

It should be noted that as the basis of mathematical modelling of innovative development of production and technological component of enterprises fundamental bases were used with the application of production function and elements of mathematical models of stochastic optimization [2].

Mathematical modelling of stochastic optimization in calculations in the direction of innovative development of production and technological component was carried out using a number of the following analysed indicators.

Mathematical simulation condition [3, 4]:
- Production of one type of innovative products is carried out, which should be used in the domestic competitive market;
- Balance of funds (f), capital efficiency (e) and production standards (β);
- There is no negative rate of profitability;
- The volume of production of innovative products is investigated with the application of linear production function in the framework of mathematical modelling of stochastic optimization.

2. Material and methods

The state of the production function in stochastic optimization of innovative development of enterprises at time t is investigated by a number of the following parameters:

- Gross innovation output (VVt) [5];
- Degree of return on fixed assets (St) [6];
- Volume of innovations introduced (VIt) [7];
- Volume of illiquid production (VNt) [8];
- Labor productivity degree (Tt) [9].

The mathematical dependence of the output of innovative products on the degree of use of fixed assets is defined in the form of a linear function. Therefore, in mathematical form, the parameters will be:

\[ VV_t = f S_t, \]  

Where \( f \) is the degree of dependence of innovation output on the degree of use of fixed assets. Then the impact of the volume of innovations introduced is determined by the formula [10]:

\[ VI_t = \beta VV_t, \]  

Moreover, the volume of illiquid production itself is determined by the formula:

\[ VN_t = (1 - \beta)VV_t, \]  

In the mathematical form, the dynamics of change of influence of financial resources is presented as follows:

\[ jS_t = eSt + \gamma \times St \times f_t, \]  

Where \( jt \) is the mathematical dependence of random wandering with continuous-time (Winer process theory).

The solution of this mathematical dependence must be performed as a function of exponential approximation according to the formula:

\[ S_t = S_0 e^{\left(e - \frac{1}{2} \gamma^2\right)t + yf_t}, \]

Where \([0; T]\).

Therefore, in the process of solving and finding the necessary indicators, the model of stochastic optimization of innovative development of enterprises using probabilistic methods will be as follows:

\[ jS_t = (-eS(t) + \beta S(t)) \times jt + \mu S(t) \times jW(t)t, \]  

Therefore, the dynamics of stochastic optimization of innovative development of enterprises should be described taking into account equations (5) and (6) in the form:

\[ jS_t = (-e + v)S(t) + \beta S(t)) \times jt + \mu S(t) \times jW(t)t, \]  

Accordingly, equation (4) will have the following solution:

\[ S_t = S_0 \exp((\beta f - e - v - 0.5 \mu^2)t + \mu W_t), \]  

For solving the obtained equation, a numerical method is used a discrete modelling approach based on discrete grids, namely: \( \{t_j\}_{j=0}^N \), where \( t_j=\infty \), \( tN=\infty \). Hence, we obtain the necessary analogue equation:

\[ S_{N+1} = S_N \exp((\beta f - e - v - 0.5 \mu^2)\Delta + \mu \sqrt{\Delta w_{i+1}}), \]

Where the function is:
\[
\Delta w_{s+1|x} = \frac{1}{\sqrt{\Delta}} (w_{s+1} - w_s),
\]

(10)

3. Results and Discussion

The presented function is characterized by the presence of a differential analogue based on a Gaussian random quantity having zero mathematical expectation and unit variance.

Testing of the presented approach and the obtained model was carried out for enterprises of the forest industry complex.

In the study, based on empirical data, a mathematical equation was obtained, the description of which is based on the dynamics of innovative development of timber enterprises for the period 2014-2019:

\[
\frac{SL}{St} = 0.03471 \times V(t),
\]

(11)

Results of mathematical simulation using computer data analysis are presented in Figure 1:

![Figure 1](image)

Figure 1 shows that the results obtained are characterized by positive dynamics of innovative development. At this dynamics, at the five-year forecast period, the rate of innovative development of timber enterprises does not exceed 8%, and there is an increase of 1.3% in growth in 2019.

Next, we will present the results of modelling and computer analysis of data in the form of a forecast of the dynamics of financial resources for the innovative development of timber enterprises. In the process of using equation (6), it is possible to use both absolute and relative indicators, and the nature of mathematical dependence will not be significantly affected. The study used a group of indicators in relative criterion values. The results of modelling stochastic optimization of innovative development of enterprises using probabilistic methods, taking into account the impact of financial resources on innovative development, are presented in Figure 2.
From Figure 2, it can be seen that the model values fluctuate at a level of not more than 9.5%. The results of the modelling of stochastic optimization are characterized by a slight positive dynamics of the increase in the investigated indicators, which indicates that the necessary limit of the impact of financial resources on the innovative development of timber enterprises has been found.

Based on using equations (9-11) of the stochastic optimization model, the dynamics of production processes of timber enterprises were analyzed, taking into account human, technological and financial resources. Results of computer analysis of data are presented graphically in Figure 3.
According to the results of the simulation of stochastic optimization and the results of computer analysis presented in Figure 3, it can be seen that the dynamics of production processes of timber enterprises, taking into account human, technological and financial resources, almost repeats the dynamics of the impact of changes in financial resources on the innovative development of timber enterprises.

We will determine the degree of stochastic influence of technological processes on the dynamics of innovative development of timber enterprises. Figure 4 presents the results of modelling.

![Figure 4. Modelling of the degree of stochastic influence of technological processes on the dynamics of innovative development of timber enterprises](image)

According to Figure 4, it can be concluded that the degree of stochastic influence of technological processes on the dynamics of innovative development of timber enterprises varies from 0 to 3.3%.

4. Conclusion
The results of modelling of stochastic optimization of innovative development of enterprises using probabilistic methods and computer analysis of data show that technological processes have in the mathematical description a significant influence on dynamics of innovative development of timber enterprises only after passing a certain time interval, within three years. Therefore, in order to model stochastic processes and forecast innovative development of timber enterprises, it is necessary to take into account the fact that technological processes, with the correct use of financial resources, produce results after a period of time, namely in 3 years.

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