Modelling approaches to the innovative development of forestry enterprises using the coefficient of random changes

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Abstract. The scientific article presents the empirical results of modelling the innovative development of enterprises related to the Russian timber industry. Modelling was carried out using the coefficient of random changes, based on the regression correlation of random variables with the inclusion of the standard deviation in the calculation. In most cases, modelling is carried out using standard methodologies based on the construction of linear and regression equations. Standard methodologies do not take into account the possibility of introducing the scientific component of innovative development into production activities at forestry enterprises, in the implementation of innovative activities. When modelling approaches to the innovative development of timber industry enterprises, the coefficient of random changes was analyzed in several variations, the values of which ranged from 0.1 to 0.73, the most optimal values were established, which demonstrate the values of sustainable growth of the studied indicators. In the course of the study, the method of approximate numerical value of stochastic differential equations was used, based on the methodology of the second order of accuracy of the integration of production indicators.

1. Introduction

The modern timber industry complex of the Russian Federation is represented by several groups of enterprises, the main of which are logging enterprises, furniture, woodworking and pulp and paper enterprises. As a part of the research, the analysis of the release of innovative products by timber industry enterprises was carried out. Figure 1 shows the dynamics of the release of innovative products at the studied enterprises [1, 2].

After analyzing the dynamics of the output of innovative products at the studied enterprises, presented in Figure 1, we can conclude that the largest volume of innovative products was noted in the group of enterprises of the pulp and paper industry, which amounted to 31,846.1 thousand rubles at the end of 2019, in most groups of enterprises there is a trend showing a decrease in the production of innovative goods.

The enterprises and organizations that are part of the Russian timber industry complex in their activities produce heterogeneous products, the production of which is associated with various factors, therefore, when modelling approaches aimed at increasing the effectiveness of innovative activities, first of all, it is important to take into account a number of specific features of the production activities of each of them.

Having analyzed the level of implementation of innovations of forestry enterprises in the structural dynamics, it is possible to clarify the fact that the scientific component of the innovative development of enterprises is considered as a stable economic and innovative system, which, when modelling
approaches, is described on the basis of linear regression equations. At timber industry enterprises, a
decrease in the volume of innovative products can be caused by a weak scientific component in
production activities; it is necessary to introduce innovations with scientific justification for the
purposes of innovative development.

![Figure 1. Dynamics of production of innovative products at timber industry enterprises for 2017 - 2020 (Forecast)](image)

Despite the application of innovations in the production process at the timber industry enterprises,
the study concluded that their number is insufficient today, innovative investments and the attraction
of personnel capable of participating in modern innovative production are needed [3,4].

2. Material and methods
The study conducted modelling approaches to innovative development, which was carried out using
the coefficient of random changes, based on stochastic differential equations [5, 6].

In the course of the study, the possibility of the influence of the scientific component of the
innovative development of the enterprise on the production and technological component was
modelled and a model was built based on stochastic differential equations, which was used in the
study:

\[
\begin{align*}
\begin{bmatrix}
sl_{t}^{(i)}(1) \\
\vdots \\
sl_{t}^{(r)}(1)
\end{bmatrix} &= \begin{bmatrix}
n_{1}^{(i)} \\
\vdots \\
n_{r}^{(i)}
\end{bmatrix} + \begin{bmatrix}
\sum_{i=1}^{n} l_{i} - 1
\end{bmatrix} \begin{bmatrix}
A_{11} & \ldots & A_{1r} \\
\vdots & \ddots & \vdots \\
A_{r1} & \ldots & A_{rr}
\end{bmatrix} - \begin{bmatrix}
B_{11} & \ldots & B_{1r} \\
\vdots & \ddots & \vdots \\
B_{r1} & \ldots & B_{rr}
\end{bmatrix} \times \begin{bmatrix}
sk_{t}^{(i)}(1) \\
\vdots \\
sk_{t}^{(r)}(1)
\end{bmatrix}
\end{align*}
\]

Where \( sl_{t}^{(i)} \) - The indicator of the increase in innovative resources of the component i, \( n^{i} \) is the
criterion for the effective use of the necessary innovative resources of the component i;
\( \Upsilon \) - Random change rate;
\( \sum_{i=1}^{r} l_{i} - 1 \) - Indicator of the efficiency of the use of financial resources allocated to technological
innovation;
\[ A; B^y \mid_{y=1}^n \] - Matrix indicator characterizing the possibility of mixed implementation of innovations (marketing, technological, environmental, etc.);

\( k_i^{(i)} \) - Independent variables of a stochastic process.

For the production, technological and scientific component of the innovative development of the enterprise, the following equation was obtained:

\[
\begin{align*}
    \mathcal{I} & = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} - \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \times \begin{bmatrix} s_{k_1^{(1)}} \\ s_{k_1^{(2)}} \end{bmatrix} \\
    \mathcal{I} & = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} - \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \times \begin{bmatrix} s_{k_1^{(1)}} \\ s_{k_1^{(2)}} \end{bmatrix} \\
\end{align*}
\]

3. Results and Discussion

In the process of solving equation (2), the method of approximate numerical value of stochastic differential equations, based on the methodology of the second order of integration accuracy, was applied:

\[
\begin{align*}
    y_{i+1}^{(1)} & = y_i^{(1)} + n^{(1)} \Delta + \beta \frac{1}{2} \sum_{j=1}^{n} \left( l_i^{(j)} + l_i^{(j)} ight) - \frac{1}{2} \left( (p_0^{(1)} + A_{11} \times p_0^{(2)}) - (B_{11} \times p_0^{(2)} + B_{12} \times p_0^{(1)}) \right) \\
    y_{i+1}^{(2)} & = y_i^{(2)} + n^{(2)} \Delta + \beta \frac{1}{2} \sum_{j=1}^{n} \left( l_i^{(j)} + l_i^{(j)} ight) - \frac{1}{2} \left( (p_0^{(1)} + A_{12} \times p_0^{(2)}) - (B_{12} \times p_0^{(1)} + B_{22} \times p_0^{(2)}) \right) \\
\end{align*}
\]

\[
\begin{align*}
    A_{11} & = \frac{1}{2} \sum_{y=1}^{x} \left( \phi_0^{(1)} \times \phi_0^{(2)} + \frac{1}{\sqrt{2}} \phi_0^{(1)} \times \phi_0^{(2)} - \phi_0^{(1)} \times \phi_0^{(2)} \right) + \Delta \\
    A_{12} & = \frac{1}{2} \sum_{y=1}^{x} \left( \phi_0^{(1)} \times \phi_0^{(2)} + \frac{1}{\sqrt{2}} \phi_0^{(1)} \times \phi_0^{(2)} - \phi_0^{(1)} \times \phi_0^{(2)} \right) + \Delta \\
\end{align*}
\]

According to the results of calculations of the system of equations (3) and (4), the values of the stochastic differential equations will have the following form:

\[
\begin{align*}
    p_0^{(1)} & = \sqrt{\Delta \phi_0^{(1)} - \Delta \phi_0^{(2)}} ; \\
    p_0^{(2)} & = \sqrt{\Delta \phi_0^{(2)} - \Delta \phi_0^{(2)}} ,
\end{align*}
\]

\[
\begin{align*}
    p_0^{(2)} & = \frac{1}{2} \frac{1}{\sqrt{2}} \sum_{y=1}^{x} \left( \phi_0^{(1)} \times \phi_0^{(2)} + \frac{1}{\sqrt{2}} \phi_0^{(1)} \times \phi_0^{(2)} - \phi_0^{(1)} \times \phi_0^{(2)} \right) + \Delta \\
\end{align*}
\]
Where \( x_{ij} \) and \( y_{ij} \) \((j=0,1,2,\ldots,2x; i=1,2,3)\) - values of random variables of exact integration.

Consequently, each step of a random variable of exact integration will have an ordinal number \( l \) ((6), (7)) in the system of random variance variables, here it is necessary to generate independent random variance values at all correlation steps by exact integration of random variables with numbers 1, 2, 3, ..., \( l-1 \).

In order to obtain the necessary solution and numerical values according to equation (1), the parameter \( n \) must be calculated by the following indicators:

1. For the production and technological component of the innovative development of a timber industry enterprise:
   \[ n = \phi \times \lambda - \nu - \alpha + 1 \]

2. For the scientific component of the innovative development of the enterprise, the equation will have the form:
   \[ n = \phi - \alpha - 1 \]

Where \( \lambda \) - indicator of innovative activity;
\( \phi \) - Rate of return;
\( \nu \) - Life cycle of innovation [7];
\( \alpha \) - Growth rate of innovation implementation efficiency [8].

The degree of variability of indicators in the obtained models (1) and (2) is integrated into the obtained numerical values of \( A \) and \( B \) of the matrix type.

Modelling was carried out with different variations of the coefficient of random changes (\( \Upsilon \)). It is fashionable to see the obtained calculation results in Figures 2. The straight line segment reflects the scientific component of the innovative development of the enterprise; the jump-like line presents data on the production and technological component of the innovative development of timber enterprises and organizations.

The value of the degree of change of indicators and criteria is estimated based on the coefficient of random changes (\( \Upsilon \)). The range of values for this coefficient is from 0 to 2 [9, 10].

In a scientific study, it was determined that in the system of innovative activities of enterprises and organizations of the timber industry complex, the necessary values of the proposed coefficient of random changes (\( \Upsilon \)) are in the range from 0.25 (logging enterprises to 0.7% (pulp and paper industry).

Based on the modeling performed and the results obtained, which are presented in the graphs (Figure 2), it can be concluded that, in general, the scientific component is being introduced into the production activities of enterprises at the timber industry enterprises, but assessing the scale of the entire timber industry complex in Russia, we can conclude that this is clearly not enough.
Figure 2. The effective values obtained on the basis of the carried out modelling for the introduction of the scientific component of innovative development into production activities at the timber industry enterprises

4. Conclusion
Analyzing the obtained results of the conducted modeling on the introduction of the scientific component of innovative development into production activities at the timber industry enterprises, it
can be concluded that there are abrupt changes in dynamics. The most acceptable for timber industry enterprises will be the option with the coefficient of random changes ($\gamma$) = 0.5. With a coefficient value of 0.73, an increase in indicators is observed at the beginning of the time interval characterized by a straight-stable section, which, in turn, led to a decrease in indicators at the end point of the graph segments. The observed decrease in a number of cases can be caused by the heterogeneity of products in all four analyzed types of timber industry (logging, furniture, woodworking, pulp and paper). Consequently, for the production and technological component of the innovative development of a timber industry enterprise, the optimal variant of the share of the scientific component ranges from 0.4 to 0.5.

Summing up, we can conclude that the obtained values of the optimal level of the share of the scientific component in order to introduce innovations at the timber industry enterprises should be 40-50%, this is caused, first of all, by the observed lag in production technologies and the need to introduce innovations (technological, environmental, marketing).

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