“Statistical model of risk assessment of insurance company’s functioning”

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Statistical model of risk assessment of insurance company’s functioning

Abstract
The article studies the basic problems of studying the risks of insurance companies’ functioning. It distinguishes the main types of risks of losses that occur during the functioning of insurers. Considering the fact that in practical activity of insurance companies not all types of risks are realized it is offered to use the algorithm of constructing a model for risk assessment of insurance companies’ operations. The model is based on the essential requirements and defining features of statistical models, including: risk assessment on the basis of probability theory.

Keywords: risk, risk of losses, statistical models of risk assessment, probability, mathematical expectations.

JEL Classification: G22, G32.

Introduction

Problem statement. The period of active market transformations in the economies of different countries, the worsening of crisis phenomena in the international financial system had a significant impact on the activity of insurance companies marked by the need to address fundamentally new challenges related to the prevention, identification and elimination of a significant increase in the concentration of risks in the insurance business. In this regard, it is necessary to carry out a thorough research of the issues related to the risks of insurance companies’ operations.

Analysis of the latest research and publications. Theoretical and methodological aspects of assessing the risks of insurance companies are reflected in the numerous works of scholars, in particular: O. Zhabynets explores the problems of classification of risks of insurance companies under conditions of European integration [7]. O. Kozmenko, V. Royenko study the risks of insurance companies in the process of investment activities [4]. O. Kozmenko and O. Kuzmenko study the fundamental formalization of the term “risk” through reinsurance operations [5]. Researcher R. Sobol explores the risks of insurance companies in the context of impact of methods of risk management on the financial condition of insurers [6].

Investigation of management of insurance risks is presented in the works of P. Bondarenko [2]. A. Boyko, V. Royenko, O. Kozhukhovska consider the assessment of risks from the point of view of insurance companies’ participation in scheme operations [1, 3].

Earlier unsolved parts of the problem. The analysis of the scientific research shows the lack of a common approach to determining the risks of insurance companies. Thus, it is increasingly important to carry out the modeling of risks of insurance companies in Ukraine because of the lack of an appropriate, adequate and objective methodology for assessing such risks.

The goal of the article is to develop a model for assessing the risks of insurance companies’ functioning.

Presentation of the main material. Today, the risks of insurance companies’ functioning are considered through the prism of losses caused by inadequate and erroneous internal processes or certain uncontrollable external events. The risks of insurance companies are characterized by a certain probability of occurrence in different combinations.

Figure 1 shows the necessity of building a statistical model of risk management of insurance companies’ functioning by using the probability approach. Therefore, the model should take into account all the peculiarities of risks of insurance companies’ functioning while meeting certain general requirements.

The key requirements to the building of statistical model of risk management for insurance company’s functioning with the use of probability approach are:
- the model should include and describe the main risk management process characteristics for insurance company’s functioning, avoiding significantly simplifying them;
- the obtained results should be similar to the actual results, for it cannot be very common to the real situation;
- the model is applicable in the making of managerial decisions;
- the model should include both quantitative and qualitative parameters of risk assessment;
- the model should be predictable and easily analyzed, letting to identify the most dangerous risk factors.

In addition to the outlined ones, the basic requirement to the model is its adequacy to the real process.

Figure 2 shows the defining features of building the model of risk assessment.
Fig. 1. Requirements to the building of statistical model of risk management for insurance company's functioning with the use of probability approach

Event $x_i$

$$R_i = P_1 R_{x_i} + ... + P_n R_{x_i}$$

Specific weight $R_{x_i}$ in the risk structure of subject 1

<table>
<thead>
<tr>
<th>Specific weight $R_{x_i}$ in the risk structure of subject 1</th>
<th>Risks inherent to a set of events $x_i$</th>
<th>Specific weight $R_{x_i}$ in the risk structure of subject 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_1$</td>
<td>$R_{x_i}$</td>
<td>$G_1$</td>
</tr>
<tr>
<td>$P_2$</td>
<td>$R_{x_i}$</td>
<td>$G_2$</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

$$R_2 = G_1 R_{x_1} + ... + G_n R_{x_n}$$

Requirements to statistical model for assessing the risks of insurance companies' functioning

- Should be homomorphic
- Should allow to identify the most dangerous risk factors
- Should provide both qualitative and quantitative risk assessment
- Reflection of the process’s essential features
- Be adequate to the studied process
- Possibility to use this model

The determining features of building a model for insurance companies’ risk assessment

- Formation of the statistical input array is based on a survey of respondents
- Assessment of risks on the basis of probability theory

Fig. 2. Building of the model of risks in the functioning of insurance companies
The goal of the survey is to receive answers to the questions regarding the presence of certain risks during the analyzed time period.

The relevance of this approach is caused by the fact that risk incidents have a qualitative nature. It is possible to quantitatively describe them only through singular and zero values.

Therefore, in order to receive the relevant information for the model of risk assessment of insurance companies’ functioning it is necessary to survey respondents with an expert method. It is proposed to gather the opinions of all representatives of insurance companies in Ukraine both in the context of risk incidents and the quantitative description of possible losses.

Another important feature in the assessment of risks is the assessment of risks in the functioning of insurance companies in the context of classical approaches based on the theory of probability. Traditionally, risk has a mathematically expressed probability of losses and can be calculated with a sufficiently high degree of reliability. Therefore, the probability is calculated on the basis of statistical data for a certain period of functioning of a particular insurance company for each risk factor.

Let us consider in detail the structure of the proposed statistical model for assessing the risks in the functioning of insurance companies.

To enter input data we will build two tables, the first of which contains $K_i$ – the absolute number of realizations of a particular risk; $S_i$ – possible losses of insurance companies in certain currencies for each risk factor in general.

The model for assessing risks in the functioning of insurance companies is shown in Figure 3.

![Fig. 3. Description of the statistical model for assessing the risks of insurance companies’ functioning](image)

As the basis of input data for assessing the risks of insurance companies’ functioning we can consider the following:

- the absolute number of realizations of a particular risk $K_i$;
- possible losses of insurance companies in certain currencies for each risk factor $S_i$.

Mathematical correlation for the model assessing the risks of insurance companies’ functioning can be presented as:

- mathematical expectations
  
  $M(X) = \bar{X} = \sum_{i=1}^{n} x_i \cdot p_i$ of monetary losses of insurance companies;

- variance $D(X) = \sum_{i=1}^{n} p_i (x_i - M(X))^2$ that characterizes the dispersion of the random variable $x(i = 1, n)$ relative to mathematical expectation $M(X)$;

- standard deviation $\sigma(X) = \sqrt{D(X)}$, which also characterizes the dispersion of the random variable relative to mathematical expectation.

Output parameters of the model for assessing the risks of insurance companies’ functioning include:

- relative potential losses of insurance company $W_i$;
- unit price of risk factor $U_i$;
- coefficient of variation.

A random event $A_i(i = 1, n)$ is considered the occurrence of factor $i$ for the risks of insurance company’s functioning ($n$ – a total number of risk factors in insurance company’s functioning). The probability of random events $A_i(i = 1, n)$ is denoted as $p_i(i = 1, n)$. We assume that some risk factors are always realized. This means that the events $A_i(i = 1, n)$ form a complete group, that is $\sum_{i=1}^{n} p_i = 1$. The
possible monetary losses of the insurance company from the occurrence of an event \( A(i = \frac{1}{1,n}) \) is denoted through \( x_i(i = \frac{1}{1,n}) \). Based on these data we can set up a series for the distribution of random variables \( x_i(i = \frac{1}{1,n}) \).

For a start, we assume that all risk factors in the functioning of insurance companies are equal. In the future, to take into account different importance of various factors it is possible to introduce the so-called weight coefficients.

It is possible to distinguish the following methods for assessing the risks of insurance company’s functioning:

1. Probability \( p(i = \frac{1}{1,n}) \) of occurrence of random event \( A(i = \frac{1}{1,n}) \), that is the probability that one or another risk factor of the insurance company’s functioning is realized.

2. Mathematical expectations

\[ M(X) = \overline{x} = \sum_{i=1}^{n} x_i \cdot p_i \] of monetary losses of insurance company.

3. Variance

\[ D(X) = \sum_{i=1}^{n} p_i(x_i - M(X))^2 \] that characterizes the dispersion of the random variable \( x_i(i = \frac{1}{1,n}) \) relative to mathematical expectation \( M(X) \).

4. Standard deviation \( \sigma(X) = \sqrt{D(X)} \), which also characterizes the dispersion of the random variable relative to mathematical expectation. If the variance is measured in square units relative to the random variable \( x_i \), then the standard deviation is measured in the same units as \( x_i \).

Let us consider this model.

At the first stage it is necessary to enter the data for \( K_i \) and \( S_i \).

\( K_i(i = \frac{1}{1,n}) \) is a number of detected encroachments on the insurance company relating to the risk factor \( i \), \( N = \sum_{i=1}^{N} K_i \) is a total number of encroachments relating to all risk factors of the insurance company’s functioning. Then, accordingly, the statistical probability (for a certain period of time) of the occurrence of risk factor \( i \) will be \( P_i = \frac{K_i}{N} \).

Possible losses of the insurance company in certain currency units are denoted as \( S_i(i = \frac{1}{1,n}) \) for each risk factor. General potential losses of the insurance company relating to the risks of its functioning will be \( S_N = \sum_{i=1}^{N} S_i \).

At the second stage, based on the values of statistical probability we calculate quantitative risk assessment of insurance companies’ functioning:

- risk of the presence of the corresponding factor, which is exactly the probability \( p_i \);
- risk of potential losses of the insurance company expressed in absolute units \( S_i \), or corresponding relative units \( W_i = \frac{S_i}{S_N} \);
- unit price of risk factor \( U_i = \frac{S_i}{K_i} \).

Let us assume that the total probability of the occurrence of different risks (information risk, risk of legislation violation, errors in the structure and functioning of internal business processes, risk of personnel qualifications and mistakes, risk of competition) equal \( p_n \), and the possible total losses have the value \( V_n \). This probability \( p_n \) consist of the sum of probabilities of each risk, that is

\[ p_n = \sum_{i=1}^{N} p_i \]. In this particular case we use equation 1:

\[ p_i = p_1 + p_2 + p_3 + p_4 \] (1)

\[ p_i = \frac{K_i}{K_s} \cdot p_s \ (i = \frac{1}{1,4}), \text{where} \]

\[ K_s = K_1 + K_2 + K_3 + K_4 \].

Then we use equation 2:

\[ p_i = p_1 + p_2 + p_3 + p_4 = \frac{K_1}{K_s} \cdot p_s + \]

\[ + \frac{K_2}{K_s} \cdot p_s + \frac{K_3}{K_s} \cdot p_s + \frac{K_4}{K_s} \cdot p_s = \]

\[ = \frac{K_1 + K_2 + K_3 + K_4}{K_s} \cdot p_s = \]

\[ = \frac{K_i}{K_s} \cdot p_s = p_s \].

Thus, we need to determine the probability \( p_i \) by means of statistical research.

There may be several ways:

1. Let us suppose that \( \Pi_t \) is the profit of insurance company (or working capital) for a certain period, and \( V_t \) is the real or potential loss of profits (or reduced working capital) during the same period. Then the statistical probability can be defined as \( p_i = \frac{V_i}{\Pi_t} \).
2. If \( N_i \) is the total number of transactions for all risk factors for a certain period, and \( N'_i \) is the number of transactions which contained threats for the property of insurance companies, then \( p_i = \frac{N'_i}{N_i} \).

3. If \( p_n \) is a statistical probability of profit losses on day \( i \) of observations

\[
0 \leq p_n \leq 1
\]

and \( N_i \) is the number of observation days, then \( p_s = \frac{\sum_{i=1}^{N_i} p_n}{N_i} \).

4. Other approaches to determining the statistical probability \( p_s \).

Let us assume that \( A_i \) is an event that is realized as risk factor \( i \).

Then the following events can be realized (equation 3). All possible combinations of options relating to the occurrence or non-occurrence of events \( A_i \) were considered (for example, \( B_i = A_1 \cdot A_2 \cdot A_3 \cdot A_4 \)). As the next step we calculate the probability \( B_i \) of each event \( (q_i = 1 - p_i \), for example \( h_2 = p(B_2) = p(A_1 \cdot A_2 \cdot A_3 \cdot A_4) = p_1 \cdot p_2 \cdot p_3 \cdot p_4 \).

The possible losses from the occurrence of event \( B_i \) will be \( x_i \), which in this case will have the following values:

\[
\begin{align*}
x_1 &= S_1 + S_2 + S_3, \\
x_2 &= S_1 + S_3 + S_4, \\
x_3 &= S_1 + S_2 + S_4, \\
x_4 &= S_1 + S_2 + S_3, \\
x_5 &= S_3 + S_4 + S_5, \\
x_6 &= S_1 + S_3, \\
x_7 &= S_1 + S_4, \\
x_8 &= S_1, \\
x_9 &= S_2 + S_3 + S_4, \\
x_{10} &= S_2 + S_3, \\
x_{11} &= S_2 + S_4, \\
x_{12} &= S_2, \\
x_{13} &= S_3 + S_4, \\
x_{14} &= S_3, \\
x_{15} &= S_4, \\
x_{16} &= 0.
\end{align*}
\]

These events will form a complete group.

In this model, the following quantitative assessments of risks of insurance companies’ functioning can be considered:

- risk of the presence of the corresponding factor, which is the probability \( h_i = p(B_i) \);
- risk of potential losses of the insurance company in case of realization of the event \( B_i \) expressed in values \( x_i \) or in corresponding relative units

\[
W_i = \frac{x_i}{S(B_i)};
\]

- unit price of risk factor \( U_i = \frac{x_i}{S(B_i)} \).

In this case \( x_s = \sum_{i=1}^{16} x_i \), \( S(B_j) \) denotes possible losses of the insurance company from the occurrence of event \( B_j \). For these distribution series we use equation 4:

\[
\begin{align*}
K(B_1) &= K_1 + K_2 + K_3 + K_4, \\
K(B_2) &= K_1 + K_2 + K_4, \\
K(B_3) &= K_1 + K_3 + K_4, \\
K(B_4) &= K_1 + K_3 + K_2, \\
K(B_5) &= K_1 + K_3 + K_4, \\
K(B_6) &= K_1 + K_2 + K_4, \\
K(B_7) &= K_1 + K_2 + K_3, \\
K(B_8) &= K_1 + K_4, \\
K(B_9) &= K_1, \quad \text{(4)}
\end{align*}
\]

We calculate mathematical expectation of losses knowing the values \( h_i \) and \( x_i \). This can be used to adjust and assess the approaches to quantitative evaluation of risks of insurance companies’ operations.

As a result, we have mathematical expectation for each group of insurance companies (equation 5):

\[
M_i(X) = \sum_{i=1}^{n} h_i \cdot x_i. \quad \text{(5)}
\]

As in the classical probability theory the calculation of mathematical expectation makes it possible to assess, which losses from risks the insurance company will bear in relative units. In other words, these are the losses relative to the total amount of losses.

In addition, in making managerial decisions it is important not only to assess the risks quantitatively, but also to take into account the fluctuations of indicators, that is, to determine the extent of variability of the results obtained from the model’s use.

Classically, the variance and standard deviation are used for this purpose.

In practice, in the calculation of the variance a simplified equation is used:

\[
D(X) = M(X^2) - M^2(X). \quad \text{(6)}
\]

The variance for each group of insurance companies is calculated with equation 6:

\[
D_i(X) = M_i(X^2) - M_i^2(X). \quad \text{(6)}
\]

Accordingly, standard deviation is calculated with equation 7:

\[
\sigma_i(X) = \sqrt{D_i(X)}. \quad \text{(7)}
\]

Variance and standard deviation of random variables demonstrate the variability of random
values relative to mathematical expectations $M_1(X)$, $M_2(X)$, $M_3(X)$ and $M_4(X)$ for the groups of insurance companies under consideration.

To determine the level of risks in the functioning of insurance companies a variation coefficient is used (equation 8):

$$\gamma_i = \frac{\sigma_i(X)}{M_i(X)} \cdot 100\%.$$  

(8)

Calculation of the variation coefficient makes it possible to analyze and approve the scale of risks in the functioning of insurance companies:

- from 0% to 10% – minimal risk;
- from 10% to 25% – low risk;
- from 25% to 50% – acceptable risk;
- from 50% to 75% – critical risk;
- from 75% to 100% – catastrophic risk.

According to this well informed managerial decisions should be made relating to risk management of insurance companies’ functioning.

**Conclusions**

We believe that this model meets all the stated requirements and organically describes risk assessment of insurance companies’ functioning.

The whole model is based on the fact that insurance companies function in uncertain conditions. Before making managerial decisions the departments of risk management of insurance companies should conduct a preliminary analysis of different types of risks by using the probability approach. This approach makes it possible to identify the most significant risk factors and to take measures aimed at minimizing the occurrence of negative consequences for companies.

An additional advantage of this model is that the model takes into consideration the company’s real activities where each risk factor may be unrealized or realized in different combinations with different levels of probability, which for one company might have negative consequences while giving advantages for another.

**References**