METHODS FOR ASSESSING LOW PROFITABILITY RISKS OF AN INVESTMENT PROJECT IN CONDITIONS OF UNCERTAINTY

MÉTODOS PARA AVALIAR RISCOS DE BAIXA RENTABILIDADE DE UM PROJETO DE INVESTIMENTO EM CONDIÇÕES DE INCERTEZA

MÉTODOS PARA EVALUAR LOS RIESGOS DE BAJA RENTABILIDAD DE UN PROYECTO DE INVERSIÓN EN CONDICIONES DE INCERTIDUMBRE

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ABSTRACT

The article discusses the methodological approach and methods for assessing the risks of decreasing the net present value *(NPV)* compared to its expected value, based on the *NPV* representation as a complex random variable with known parameters of its distribution. It is substantiated that this *NPV* representation is a consequence of random conditions for the implementation of investment projects, their financial inflows and outflows, as well as discounts. According to the law of large numbers, it is advisable to consider the *NPV* distribution as normal. Based on the *NPV* expansion into the Taylor series at the point of its mathematical expectation (expected value), an analytical expression for the *NPV* dispersion is obtained as a function of the expected values and dispersions of financial flows and discounts. The authors of the article discuss the possibilities of assessing these *NPV* characteristics based on available project statistics and expert data. Depending on the attitude to risk, possible indicators of the risks of an investment project can be the average risk of a decrease in the *NPV* or any quantile of its decrease with due regard to the distribution parameters of this indicator limited from above by its mathematical expectation. The proposed approach to assessing the risks of reducing the efficiency of investment projects is characterized by less subjectivity compared to its analogs based on the methods of varying the discount rate and reliable equivalents.

Keywords: investment project, efficiency, net present value, random variable, distribution law, risk, quantile, dispersion, Taylor series.

RESUMO

O artigo discute a abordagem metodológica e os métodos de avaliação dos riscos de diminuição do valor presente líquido (VPL) em relação ao seu valor esperado, com base na representação do VPL como uma variável aleatória complexa com parâmetros conhecidos de sua distribuição. Constata-se que esta representação do VPL é consequência de condições aleatórias de implementação de projetos de investimento, das suas entradas e saídas financeiras, bem como de descontos. De acordo com a lei dos grandes números, é aconselhável considerar a distribuição do VPL como normal. Com base na expansão do VPL para a série de Taylor no ponto de sua expectativa matemática (valor esperado), obtém-se uma expressão analítica para a dispersão do VPL em função dos valores esperados e das dispersões dos fluxos financeiros e descontos. Os autores do artigo discutem as possibilidades de avaliar essas características do VPL com base nas estatísticas de projetos disponíveis e em dados de especialistas. Dependendo da atitude em relação ao risco, possíveis indicadores dos riscos de um projeto de investimento podem ser o risco médio de uma diminuição do VPL ou qualquer quantil da sua diminuição tendo em devida conta os parâmetros de distribuição deste indicador limitados de cima pela sua expectativa matemática . A abordagem proposta para avaliar os riscos de redução da eficiência dos projetos de investimento é caracterizada por menos subjetividade em comparação com seus análogos baseados em métodos de variação da taxa de desconto e equivalentes confiáveis.

Palavras-chave: projeto de investimento, eficiência, valor presente líquido, variável aleatória, lei de distribuição, risco, quantil, dispersão, série de Taylor.

RESUMEN
El artículo analiza el enfoque metodológico y los métodos para evaluar los riesgos de disminuir el valor actual neto (VAN) en comparación con su valor esperado, basado en la representación del VPN como una variable aleatoria compleja con parámetros conocidos de su distribución. Se fundamenta que esta representación del VAN es consecuencia de condiciones aleatorias para la implementación de proyectos de inversión, sus entradas y salidas financieras, así como los descuentos. Según la ley de los grandes números, es aconsejable considerar la distribución del VPN como normal. A partir de la expansión del VPN en la serie de Taylor en el punto de su expectativa matemática (valor esperado), se obtiene una expresión analítica para la dispersión del VPN en función de los valores esperados y las dispersiones de los flujos financieros y los descuentos. Los autores del artículo discuten las posibilidades de evaluar estas características del VPN basándose en las estadísticas de proyectos disponibles y los datos de expertos. Dependiendo de la actitud ante el riesgo, los posibles indicadores de los riesgos de un proyecto de inversión pueden ser el riesgo promedio de una disminución del VAN o cualquier cuantil de su disminución teniendo debidamente en cuenta los parámetros de distribución de este indicador limitado desde arriba por su expectativa matemática. . El enfoque propuesto para evaluar los riesgos de reducir la eficiencia de los proyectos de inversión se caracteriza por una menor subjetividad en comparación con sus análogos basados en métodos de variación de la tasa de descuento y equivalentes confiables.

Palabras clave: proyecto de inversión, eficiencia, valor actual neto, variable aleatoria, ley de distribución, riesgo, cuantil, dispersión, serie de Taylor.

1. INTRODUCTION

Entrepreneurs usually make decisions on investing their capital in projects after comparing their expected efficiency and possible risks. In the relevant scientific literature, there are similar opinions regarding the composition of performance indicators for investment projects (Kovalev, 2003; Sharp et al., 2018; Tikhomirov & Tikhomirova, 2020; Vilenskii et al., 2015). In general, they can be divided into two groups: main and auxiliary.

The main indicators include the accumulated cash flow for the period of project implementation *(planned value, PV)* for assessing the effectiveness of short-term projects and the net present value (*NPV*). Unlike the *PV*, it considers the reduction in the expected values of financial flows for the project in future periods compared to the current discount. It is assumed that discounting enhances the comparison of the effectiveness of projects that have different execution periods, which is important when their duration is significant, especially in the real economy (Livshits et al., 2019; Sirotkin & Kelchevskaya, 2022). The auxiliary performance indicators usually include the internal rate of return *(IRR)* on capital investments defined as the discount at which the amount of financial receipts from the project is equal to the amount of capital invested for the entire period of implementation, the payback period (PP) of capital investments *(PP* is the period, for which the discounted amounts of financial receipts and investments for the project are equalized) and others (profitability index, average project profitability, etc.).

In practice, investors prefer projects with higher *NPV*, assuming that this indicator gives a reasonable idea of the effectiveness of a particular project despite abstract and ambiguous assumptions (Livshits et al., 2019; Zimin, 2013). The indicator is not confirmed by financial statements and is calculated based on projected financial flows for the project in conditions of uncertainty. The *NPV* is sensitive to discounts, whose values are selected subjectively. The *NPV* becomes ambiguous when there are several project implementation strategies, etc.

The auxiliary indicators of the effectiveness of investment projects *(IRR, PP)* directly depend on the level of *NPV*, although they contain additional information, primarily about their reliability. Projects with large *IRR* and shorter *PP* provide guarantees to investors that they will not incur significant losses in the event of possible unfavorable changes.

However, when focusing on the *NPV* as the main criterion for the effectiveness of an investment project, theory and practice experience difficulties in assessing the risks of reducing the expected values, which characterize losses in the project's profitability compared to its expected level. In general, these losses may be due to an increase in payments, a decrease in project revenues, or an increase in discounts (for example, due to higher inflation) compared to its expected values in the future.

The situation is complicated by the fact that there can be risky (unfavorable) changes in the amount of payments and receipts under the project each year. For example, an increase in the amount of payments may be due to an increase in the expected prices for the raw materials or equipment necessary for the creation of a facility (market risks), accidents during the transportation of goods or construction of a facility (accident risks), failure by contractors to fulfill the terms of contracts (delays in their execution and even non-performance) due to unfavorable amendments in legislation, inter-country contradictions, etc., and public, political, and other risks at the stage of creating an object, whose activities should bring income to investors. This income may also decrease compared to its expected value due to a decrease in prices for the products manufactured by the facility, accidents during its production and delivery, a decrease in demand, etc. The total risk of reducing the effectiveness of the project caused by a set of such negative changes is quite difficult to assess (Kovalev, 2017; Sazonov et al., 2014; Troitskaya, 2020). In such a situation, the theory recommends using simplified procedures when assessing this indicator. These include the method of varying the discount rate, the method of estimating reliable equivalents, etc. (Bekimbetova & Shaturaev, 2021; Tikhomirov & Tikhomirova, 2020; Vilenskii et al., 2015). In particular, the method of varying the discount rate is based on the assumption that the risk of a decrease in the *NPV* of the project is reflected by an increased discount rate (usually determined by experts). The amount of such risk is calculated using the following formula:

$$R(NPV) = NPV(E_0) - NPV(E_1) \quad (1)$$

Where:

- $R(NPV)$ is the risk of reducing the *NPV* of the project;
- $NPV(E_0)$ is the *NPV* of the project based on the E_0 discount rate;
- $NPV(E_1)$ is the *NPV* of the project estimated at an increased discount rate $E_1 > E_0$ reflecting the impact of the entire set of unfavorable conditions on this indicator.

The method of estimating reliable equivalents is based on the assumption that the total risk of reducing the effectiveness of the *NPV* of the project can be assessed by analogy with formula (1) as the difference between the value of this indicator determined at the expected annual levels of payment and receipt flows and its value calculated with due regard to possible unfavorable changes (Batkovskii et al., 2015; Livshits et al., 2019; Tikhomirov & Tikhomirova, 2020).

The estimated risks of a decrease in the *NPV* of the project obtained using these methods are characterized by significant uncertainty and subjectivity due to the difficulties of choosing discount values and flows of payments and receipts that reflect the expected unfavorable changes in their levels.

In our opinion, increasing the reliability of the *NPV* reduction risk assessments can be achieved by considering the distribution law of this indicator. Possible options for such estimates (an average risk of the *NPV* decline, quantiles of risk of the *NPV* decline) have specific statistics. They can be calculated as the differences between the expected (base) NPV_0 value and the average value and quantiles corresponding to different probabilities of not exceeding their levels defined in the $NPV < NPV_0$ area. With a distribution density function of the *NPV* ($f(NPV) = f(x)$), the average risk of its reduction can be estimated as the difference between the value and the average value of this indicator in the $NPV < NPV_0$ area based on the following formula:

$$\bar{R}(NPV) = \left(x_0 - \frac{\int_{-\infty}^{x_0} xf(x)dx}{\int_{-\infty}^{x_0} f(x)dx} \right) \int_{-\infty}^{x_0} f(x)dx \qquad (2)$$

Where:

- the x variable denotes the *NPV* $x_0 = NPV_0$;
- $\int_{-\infty}^{x_0} f(x)dx$ is the probability that the *NPV* is in the $NPV < NPV_0$ area. With the symmetric function $f(x)$, the value of this probability is 0.5.

Formula (2) determines the unconditional average value of the risk of reducing the *NPV*, and its part in parentheses is the conditional average value (if $NPV < NPV_0$).

Similarly, quantiles of the risk of the *NPV* falling below the NPV_α level, where α is the probability of the event, can be estimated based on the following formula:

$$R(NPV_\alpha) = \left(NPV_0 - NPV_\alpha\right) \cdot \alpha \qquad (3)$$

where NPV_α is the *NPV* based on the condition:

$$\int_{-\infty}^{x_\alpha} f(x)dx = \alpha \qquad (4)$$

where α is the probability that the *NPV* will not exceed the $NPV_\alpha = x_\alpha$ level.

From a set of such indicators ($\bar{R}(NPV)$, $R(NPV_\alpha)$ for a specific project, each investor can choose a suitable value as the risk of reducing the *NPV* with due regard to their attitude to risk, the resources to compensate for risky losses, and other factors. However, this approach faces the problem of forming the *NPV* distribution density function. One of the possible solutions is the use of the simulation method (Batkovskii et al., 2015; Platon & Constantinescu, 2014). Under this method, the function is formed on a set of *NPV* values estimated for various possible combinations of discounts and financial flows of the project, taking into account their probabilities. For each real project, the number of such combinations can be large, and their likelihood is difficult to assess due to the lack of sufficient statistics. As a result, it is difficult to implement this method. We consider an alternative analytical method for constructing the *NPV* distribution density function based on the representation of this indicator as a complex random variable, whose distribution parameters depend on the distributions of its components (discounts and flows), their mathematical expectations, and variances, whose values can be estimated based on statistics on the implementation of alternative projects, expert assessments, and other methods.

The study aims to develop methods for assessing the risks of reducing the efficiency of investment projects represented by the *NPV* indicator. The latter is regarded as a complex random variable formed by a set of random components.

2. METHODS

The *NPV* representation of an investment project as a complex random variable is based on the assumption that all its components are random variables generally characterized by different distribution laws but with known parameters (mathematical expectations and variances):

$$NPV = \sum_{t=1}^{T} \frac{\hat{\Pi}_t - \hat{O}_t}{(1+\hat{E})^t} = \sum_{t=1}^{T} \frac{\hat{z}_t}{(1+\hat{E})^t} \quad (5)$$

Where:

- NPV, $\hat{\Pi}_t$, $\hat{O}_t$, $\hat{E}$ are random variables (NPV, Π_t inflows and O_t outflows of financial resources for the project in the t year, E discount);
- T is the project implementation period $\hat{z}_t = \hat{\Pi}_t - \hat{O}_t$.

Substituting random variables in the right side of formula (5) with their mathematical expectations $M[\Pi_t]$, $M[O_t]$, $M[E]$, we obtain the following mathematical expectation of the NPV – $M[NPV] = NPV_0$. At the same time, the variables included in the right side of formula (5) are considered the sum of simpler (elementary) components of inflows and outflows of financial resources for the project (costs of raw materials, equipment, goods, losses from accidents, etc.):

$$\hat{\Pi}_t = \sum_{i=1}^{I} \hat{\Pi}_{it}, \hat{O}_t = \sum_{j=1}^{J} \hat{O}_{jt} \quad (6)$$

Where:

$i = \overline{1, I}$, $j = \overline{1, J}$ are indicators of the elementary components of financial inflows and outflows of the project.

With a natural assumption about the independence of the elementary components of inflows and outflows in each t period and relating to different periods, the following formulas are valid, characterizing the mathematical expectations and variances of the numerator of formula (5) and its indicators:

$$M\left[\hat{\Pi}_t\right] = \sum_{i=1}^{I} M\left[\hat{\Pi}_{it}\right], \; M\left[\hat{O}_t\right] = \sum_{j=1}^{J} M\left[\hat{O}_{jt}\right]$$
$$M\left[\hat{z}_t\right] = M\left[\hat{\Pi}_t\right] - M\left[\hat{O}_t\right] \quad (7)$$

$$\sigma^2\left[\hat{\Pi}_t\right]=\sum_{i=1}^{I}\sigma^2\left[\hat{\Pi}_{it}\right],\ \sigma^2\left[\hat{O}_t\right]=\sum_{j=1}^{J}\sigma^2\left[\hat{O}_{jt}\right]$$
$$\sigma^2\left[\hat{z}_t\right]=\sigma^2\left[\hat{\Pi}_t-\hat{O}_t\right]=\sigma^2\left[\hat{\Pi}_t\right]+\sigma^2\left[\hat{O}_t\right]$$

with a sufficiently wide range of Π_{it}, O_{jt} values and in conformity with the law of large numbers, it can be assumed that the random *NPV* is distributed according to the normal law (in practice, investors can be guided by another law of the *NPV* distribution if there are sufficient grounds). The mathematical expectation of NPV_0 can be estimated using formula (5), substituting the mathematical expectations of the corresponding variables in the right side.

Estimating the *NPV* dispersion is a more complex task, although with a deterministic value of the *E* discount this indicator is calculated using a simple formula:

$$\sigma^2\left[NPV\right]=\sum_{t=1}^{T}\frac{\sigma^2\left[\hat{z}_t\right]}{(1+E)^{2t}} \tag{8}$$

However, if the *E* discount is also a random variable, the *NPV* variance should be defined as the variance of the ratio of two random variables (i.e., as the variance of a complex random variable). In the general case, the dispersion of a complex random variable $\hat{y}=f(\hat{x}_1,...,\hat{x}_n)$ functionally dependent on random variables $\hat{x}_i$, $i=\overline{1,n}$, can be determined based on the expansion of the *f* function in the Taylor series (Tikhomirov & Tikhomirova, 2020):

$$\hat{y}=f(\overline{x}_1,...,\overline{x}_n)+\sum_{i=1}^{n}\frac{\partial f(\overline{x}_1,...,\overline{x}_n)}{\partial x_i}(\hat{x}_i-\overline{x}_i) \tag{9}$$

where $\overline{x}_i$ is the mathematical expectation of a random variable $\hat{x}_i$, $i=\overline{1,n}$.

Considering formula (9), the variance of the random $\hat{y}$ variable can be determined based on the following expression:

$$\sigma_{\hat{y}}^2 = M\left[\hat{y} - M\left[\bar{y}\right]\right]^2 = M\left[\sum_{i=1}^{n} \frac{\partial f(\bar{x}_1,...,\bar{x}_n)}{\partial x_i}(\hat{x}_i - \bar{x}_i)\right]^2 =$$
$$= M\left[\frac{\partial f(\bar{x}_1,...,\bar{x}_n)}{\partial x_1},...,\frac{\partial f(\bar{x}_1,...,\bar{x}_n)}{\partial x_n}\right] \cdot Cov(\hat{x}) \times \left[\frac{\partial f(\bar{x}_1,...,\bar{x}_n)}{\partial x_1},...,\frac{\partial f(\bar{x}_1,...,\bar{x}_n)}{\partial x_n}\right]^* \quad (10)$$

where $Cov(\hat{x})$ is the covariance matrix of a random vector $(\hat{x}_1,...,\hat{x}_n)$; the symbol * characterizes a column vector.

When representing *NPV* components at different times in the form of ratios $\hat{y}_t = \frac{\hat{z}_t}{(1+\hat{E})^t}$, $t = \overline{1,T}$, formula (10) for each *t* takes the following form:

$$\sigma^2(\hat{y}_t) = \left[\frac{\partial y_t}{\partial z_t}, \frac{\partial y_t}{\partial u_t}\right] \cdot \begin{bmatrix} \sigma_{z_t}^2 & 0 \\ 0 & \sigma_{u_t}^2 \end{bmatrix} \cdot \begin{bmatrix} \frac{\partial y_t}{\partial z_t} \\ \frac{\partial y_t}{\partial u_t} \end{bmatrix} \quad (11)$$

where $u_t = (1+\hat{E})^t$.

Adding variables $\frac{\partial y_t}{\partial z_t} = \frac{1}{M[\hat{u}_t]}$ and $\frac{\partial y_t}{\partial u_t} = -\frac{M[\hat{z}_t]}{(M[\hat{u}_t])^2}$, to formula (11), we get the following formula:

$$\sigma^2(\hat{y}_t) = \frac{(M[\hat{u}_t])^2 \cdot \sigma_{z_t}^2 - (M[\hat{z}_t])^2 \cdot \sigma_{u_t}^2}{(M[\hat{u}_t])^4} \quad (12)$$

where

$$\sigma_{u_t}^2 = t^2 \cdot \left(1 + M\left[\hat{E}\right]\right)^{2(t-1)} \cdot \sigma_{\hat{E}}^2, M[\hat{u}_t] = \left(1 + M[\hat{E}]\right)^t \quad (13)$$

Considering formulas (12) and (13), the final dispersion of the ratio $\frac{\hat{z}_t}{(1+\hat{E})^t}$ will take the following form:

$$\sigma^2\left[\frac{\hat{z}_t}{(1+\hat{E})^t}\right]=\frac{\sigma_{z_t}^2+\left(M[\hat{z}_t]\right)^2\cdot t^2\cdot\left(1+M[\hat{E}]\right)^{-2}\cdot\sigma_E^2}{\left(1+M[\hat{E}]\right)^{2t}} \quad (14)$$

Assuming that the relationships $\frac{\hat{z}_t}{(1+\hat{E})^t}$ are independent, the *NPV* dispersion is determined using the following formula:

$$\sigma^2\left[NPV\right]=\sum_{t=1}^{T}\sigma^2\left[\frac{\hat{z}_t}{(1+\hat{E})^t}\right] \quad (15)$$

3. DISCUSSION

This approach to assessing the risk of reducing the *NPV* of an investment project presupposes the availability of sufficient information to assess the possible distributions of financial flows $\sigma^2\left[\hat{\Pi}_t\right]$ and outflows $\sigma^2\left[\hat{O}_t\right]$ in each year *(t)*. Such information may exist for typical and frequently implemented projects (the construction of shopping centers, thermal power plants, etc.) in the form of real estimates of the elementary components of their financial flows $\hat{\Pi}_{it}^k, \hat{O}_{jt}^k$, where *k* is the project index; *i* and *j* are the indices of the elementary components of inflows and outflows. Based on these values, it is possible to calculate the dispersions $\sigma^2\left[\hat{\Pi}_{it}^k\right]$ and $\sigma^2\left[\hat{O}_{jt}^k\right]$, while formula (7) can be used to estimate the variance $\sigma^2\left[\hat{\Pi}_t\right], \sigma^2\left[\hat{O}_t\right]$.

In the absence of such information, when determining the required variances $\sigma^2\left[\hat{\Pi}_t\right]$ and $\sigma^2\left[\hat{O}_t\right]$, expert assessments can be used, based on the results of quantitative and qualitative analysis of variations in financial flows and outflows for the project. Considering more subjective discounting of each project, expert assessment is the most preferable method for determining its variance.

In conditions of significant uncertainty in the estimated financial inflows, outflows, and discounts of the project, when determining the risk of reducing the *NPV*, interval estimation methods can be used based on expert estimates (in this case, the limits of these indicators) (Shvetsova et al., 2018; Tikhomirov & Tikhomirova, 2020). The initial data for implementing these methods are the lower and upper limits of the intervals of the *NPV* components: financial flows and discounts in each year *t*. The lower limits of these indicators are Π_t^1, O_t^1, E_1. The upper limits are Π_t^2, O_t^2, E_2. Based on these data and using the rules of interval arithmetic, it is possible to determine the lower and upper limits of the *NPV* existence interval $NPV -\ NPV_1$ and NPV_2, respectively:

$$NPV_1 = \frac{\sum_{t=1}^{T} (\Pi_t^1 - O_t^2)}{(1+E_2)}$$

$$NPV_2 = \frac{\sum_{t=1}^{T} (\Pi_t^2 - O_t^1)}{(1+E_1)}$$

The expected *NPV* is usually assigned to the middle of the interval of the indicator $NPV_0 = \frac{1}{2}(NPV_1 + NPV_2)$.

The risky *NPV* can be determined using the Hurwitz criterion and a subjective indicator of investor pessimism $\lambda \geq 0{,}5$:

$$NPV_R = \lambda \cdot NPV_1 + (1-\lambda) \cdot NPV_2$$

Considering these indicators, the risk of a decrease in the *NPV* can be assessed by analogy with formula (1):

$$R_{NPV} = NPV_0 - NPV_R$$

4. CONCLUSIONS

The methods considered in this article correctly determine the *NPV* downside risk as a random indicator depending on the totality of its random components (financial flows and discounts) with due regard to the investor's attitude to risk, which is a subjective characteristic. This is their main advantage. However, these methods also have disadvantages. In particular, they imply the need for significant amounts of initial information reflecting mathematical expectations and dispersion of the elementary components of the *NPV*, which, if it is not available, can be supplemented by expert estimates. This to an extent reduces the reliability of the results. In addition, obtaining such arrays of source data is a labor-intensive procedure.

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