REICE
Revista Electrónica de Investigación en Ciencias Económicas
Abriendo Camino al Conocimiento
Área de Conocimiento de Ciencias Económicas y Administrativas
Universidad Nacional Autónoma de Nicaragua, Managua (UNAN-Managua)

Vol. 12, No. 24, julio – diciembre 2024 **REICE ISSN: 2308-782X**
https://revistas.unan.edu.ni/index.php/reice
revista.reice@unan.edu.ni

Modeling the formation of an asset portfolio with risk optimization

Modelado de la formación de una cartera de activos con optimización del riesgo

Fecha de recepción: julio 05 de 2024
Fecha de aceptación: septiembre 12 de 2024
DOI: https://doi.org/10.5377/reice.v12i24.20065

Irina Kiseleva*
Plekhanov Russian University of Economics, Moscow, Russian Federation
*Corresponding author Email: kia1962@list.ru
ORCID: https://orcid.org/0000-0001-8862-2610

Aziza Tramova
Plekhanov Russian University of Economics, Moscow, Russian Federation
Email: g.tramova@yandex.ru
ORCID: https://orcid.org/0000-0002-4089-6580

Layla Mangusheva
Plekhanov Russian University of Economics, Moscow, Russian Federation
Email: mangusheva.ls@rea.ru
ORCID: https://orcid.org/0009-0004-2408-6248

Elena Chernikova
Russian Presidential Academy of National Economy and Public Administration (RANEPA), Russian Federation
Email: chernikova@mymail.academy
ORCID: https://orcid.org/0000-0002-2978-5126

Bayasgalan Tsetsgee
Mongolian University of Science & Technology (MUST), School of Business Administration and Humanities (SBH), Ulaanbaatar, Mongolia
Email: tsetsgee5873@gmail.com
ORCID: https://orcid.org/0000-0002-7074-1205

Abstract

This article authors investigate and study the modeling of the decision-making process under risk conditions. The purpose of this article is to identify the main patterns that determine the features of risk assessment in business as a key element contributing to the economic security of an organization, as well as to conduct a comparative analysis of methods for assessing and managing investment risks. The optimality of the investment portfolio is the highest priority task for decision-makers who want to achieve maximum returns with minimal risks. The article examines various directions of investor fund allocation to achieve maximum profit. An analysis of models and methods that allow investors to take into account the expected returns and risks of various assets when forming a portfolio is conducted. It is concluded that it is impossible to increase income without increasing risk or reduce risk without decreasing profit. The most diversified and best yielding portfolio per unit of risk will be one that contains the most risky assets.

Keywords: Optimization, Risk Management, Model, Financial Activities, Decision Making, Investments.

Resumen

En este artículo, los autores investigan y estudian la modelización del proceso de toma de decisiones en condiciones de riesgo. El objetivo de este artículo es identificar los patrones principales que determinan las características de la evaluación de riesgos en los negocios como un elemento clave que contribuye a la seguridad económica de una organización, así como realizar un análisis comparativo de los métodos de evaluación y gestión de los riesgos de inversión. La optimalidad de la cartera de inversiones es la tarea de máxima prioridad para los tomadores de decisiones que desean lograr la máxima rentabilidad con los mínimos riesgos. El artículo examina varias direcciones de asignación de fondos de los inversores para lograr el máximo beneficio. Se realiza un análisis de modelos y métodos que permiten a los inversores tener en cuenta la rentabilidad esperada y los riesgos de varios activos al formar una cartera. Se concluye que es imposible aumentar los ingresos sin aumentar el riesgo o reducir el riesgo sin disminuir los beneficios. La cartera más diversificada y con mejor rendimiento por unidad de riesgo será aquella que contenga los activos más riesgosos.

Palabras claves: Optimización, Gestión de riesgos, Modelo, Actividades financieras, Toma de decisiones, Inversiones.

Introduction

This article considers various methods of optimizing the risks of forming an asset portfolio. The practical task will be considered using the example of shares of four major oil companies.

The relevance of the work is that more and more investors in securities are emerging in the modern financial market. Many people and companies use the practice of creating an asset portfolio for various purposes, including increasing their income. This practice has spread everywhere, and now you can even assemble your own portfolio without leaving home. However, for this asset portfolio to be profitable, one must have knowledge in the field of assessing the risks of this portfolio.

Main Approaches to Optimizing Portfolio Formation Risks. Analysis of Portfolio Formation Models

The main task of portfolio optimization is the correct selection of assets that will enter the portfolio. It is necessary to make the formed portfolio bring as much profit as possible with the least risks. There are many different assets on the market, and we need to choose those that meet all the necessary requirements of the decision-maker to achieve the best result for a given period (Rybakov et al., 2022). To achieve this, various criteria can optimize the portfolio. In this task formulation, the best result is usually understood as the portfolio that achieves maximum profitability with minimal risks (Degtev et al., 2022). This takes into account various external environment constraints, the level of initial capital, and the preferences of the person forming the portfolio (Behrens, Havranek, 2005; Damodaran, 2004; Ivanyuk, 2019).

Let's consider several types of specific asset portfolios. The first is an investment portfolio. An investment portfolio is understood as a collection of different securities. This portfolio is the property of one investor and is managed by them as a single asset. A diversified portfolio is a collection of assets where all securities (or types of securities) are equal. The main advantage of diversification is that it reduces the overall level of risk by diversifying the assets within the portfolio. Thus, it can be

concluded that portfolio profitability and risk are key concepts that need to be understood when creating an asset portfolio. Optimization of a securities portfolio involves forming asset proportions that provide maximum return with minimal risk. It is also necessary to consider that the securities market constantly changes, and to keep the portfolio optimal, it must be constantly monitored, taking into account all changes in the market. Portfolio management is necessary for this (Attekkov et al., 2013; Gibson, 2016; Dementyeva, 2015).

Market price risks of a bank, depending on the specific task of risk analysis and the available initial information, can be assessed by both direct indicators of possible losses and indirect ones (dispersions, semi-dispersions, etc.). If there is sufficient initial information, such as time series of average daily price levels over a long period, risk assessments by direct and indirect indicators can be obtained based on distributions of forecast values of asset returns. Such a distribution for a certain moment (day) of an asset (asset portfolio) transaction can be formed as distributed forecast price (return) errors obtained based on, for example, financial econometric models. This distribution characterizes the statistical regularities in price deviations from the expected level in either direction (Khasanov, Savrasova, 2016; Domashchenko, Finogenova, 2010). A model describing the dynamics of asset returns at consecutive time points can be represented by the following equation linking the return at time t with its previous values and the error:

$$\mu_t = f(\mu_{t-1}, \dots, \mu_{t-n}) + \varepsilon_t \qquad (1)$$

In this case, the risk area of return reduction is determined by the following values (Figure 1):

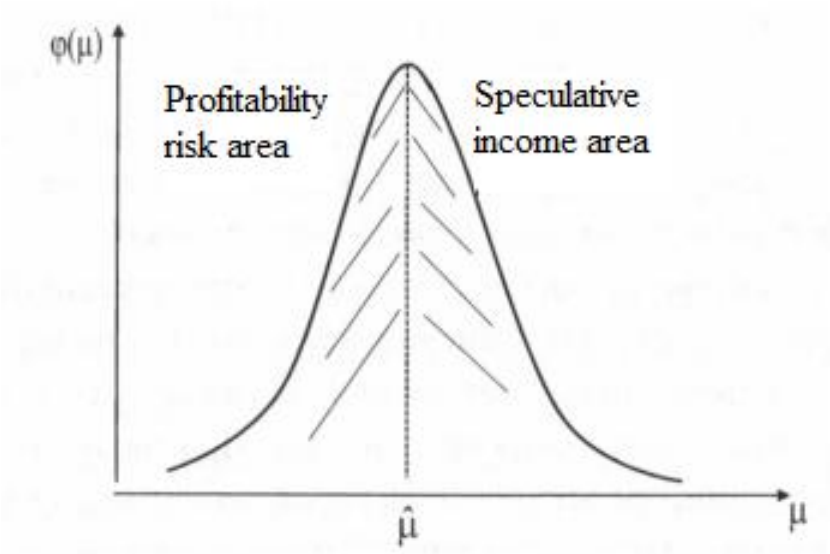

Figure 1. Distribution density of returns and associated areas of risk reduction and speculative returns

For this area (provided this reduction took place), for example, the conditional average losses from the return reduction can be estimated as the difference between its expected value and the average level in the risk area:

$$\overline{MR}(\mu) = \hat{\mu}_t - [\int_{-\infty}^{\hat{\mu}_t} \mu_t \varphi(\mu_t) dt\,] / \int_{-\infty}^{\hat{\mu}_t} \varphi(\mu_t) dt \qquad (2)$$

The subtracted part on the right side characterizes the average return in the risk area, and its denominator is the probability of falling into this area. In the case of symmetric return distributions, this probability is 0.5.

Markowitz model

Next, let's consider the Markowitz model (Watsham, Parramore, 1999; Foss, 2007; Morrow et al., 2007). In this task, the problem of choosing the optimal portfolio is reduced to the theory of an efficient set of portfolios or the so-called efficiency frontier. The essence of the theory is: if an investor has access to n securities, each with its expected return E(r) where i = 1, 2... n, there will be only one combination of securities in the portfolio that minimizes the portfolio risk for each given value of the

expected portfolio return. Figure 2 shows that whatever the expected return value defined by the investor, by iterating the weights of the portfolio securities, one can always find at least one such portfolio in which the risk level reaches a minimum value (in Fig. 2 – point M).

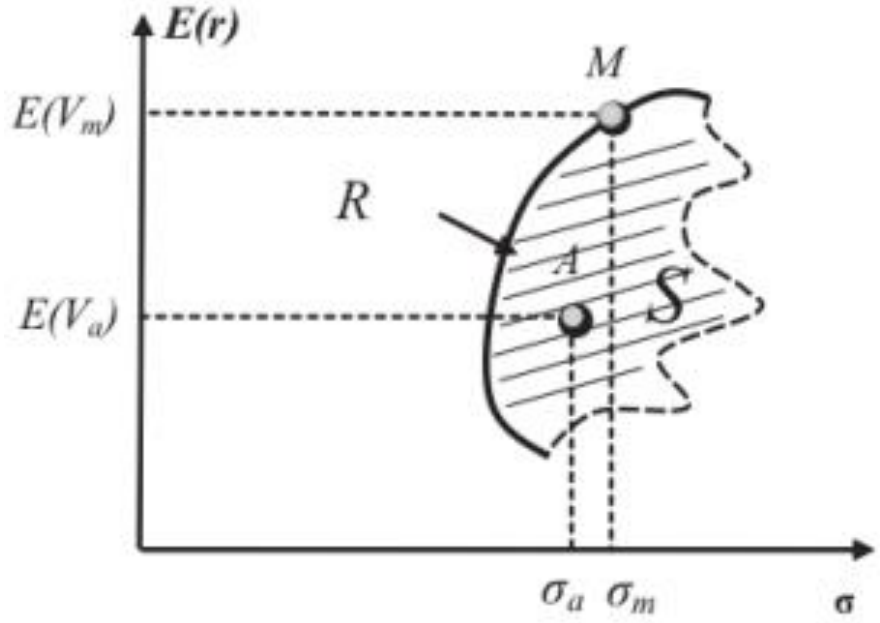

Figure 2. The relationship between return and risk

The expected return on a security in the Markowitz model is calculated as the mathematical expectation of its returns over a past period, and the risk is the standard deviation of these returns (Kiseleva et al., 2023). Based on this, several conclusions can be drawn: first, if the correlation coefficients between asset returns in different portfolios are constant, then changing the ratio of securities in the portfolio also changes the portfolio risk; second, for any portfolio, the risk decreases as the correlation coefficient of securities decreases. The set of portfolios that minimize the risk level for each expected return value forms the so-called efficiency frontier (in Fig. 2, this is line R). As seen in the figure, when moving along the frontier upwards to the right, the values of E(r) and dispersion increase, and when moving downwards to the left, they decrease. An efficient portfolio is a portfolio that provides minimal risk for a given E(r) or maximum return for a given risk level. In the Markowitz model, the

investor's task is reduced to the following: from the set of portfolios with the expected return rate E(rm), it is necessary to find the one that ensures the minimum risk level. In other words, the investor's task can be reduced to solving the following system:

$$\begin{cases} E(r_p) = \sum_{i=1}^{n} x_i [E(r_i) \rightarrow max; \\ \sigma_p = \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{n} \sigma_{ij} x_i x_j} \rightarrow min; \\ \sum_{i=1}^{n} x_i = 1; \\ x_i \geq 0 \end{cases}$$

This model has several significant drawbacks.

The model is based on the average return data from past periods, so it is rational to use it only in a stable state of the stock market.

The assumption of normal return distribution is not always met, so mathematical expectation and standard deviation cannot serve as adequate measures of return and risk.

There are situations where the multiplicity of asset values leads to the forced addition of integer constraints. This increases the task's dimension and complexity of its solution.

In this work, the authors consider various models and approaches to portfolio optimization, including the Sharpe model, the Markowitz model, and methods based on statistical analysis and optimization theory. It is proven that these methods allow investors to consider the expected returns and risks of various assets when forming a portfolio.

Sharpe Model

The Sharpe model for portfolio formation is based on using the Sharpe ratio, which helps investors make decisions about balanced investment allocation. The goal of this model is to maximize portfolio returns for a given risk level (Sharpe et al., 2001).

The process of forming a portfolio using the Sharpe model includes the following steps:

Assessing the expected return and risk of each asset: The investor should evaluate the expected return and standard deviation (risk) of each asset in which they plan to invest.

Calculating the Sharpe ratio for each asset: For each asset, it is necessary to calculate the Sharpe ratio using the formula (Ri - Rf) / σi, where Ri is the expected return on the asset, Rf is the risk-free interest rate, and σi is the standard deviation of the asset's return.

Determining the optimal portfolio: Considering the Sharpe ratios and the associated risk level, the investor can determine the optimal portfolio that combines different assets to maximize the portfolio's Sharpe ratio.

Rebalancing the portfolio: The investor should periodically review and rebalance the portfolio considering changes in asset returns and risks.

The Sharpe model for forming a portfolio of assets helps investors make more informed decisions about their investment allocation, considering both potential returns and the risk level of assets.

Tobin Model

The Tobin model with a risk-free asset in forming a securities portfolio is a way of portfolio optimization that considers the presence of a risk-free asset such as

government bonds or other investments with zero risk (Trofimov, Trofimova, 2013; Firsova, Melnik, 2015; Khokhlov, 2003).

The main idea of the Tobin model with a risk-free asset is that an investor can complement their stock portfolio with a risk-free asset to reduce the overall risk level. By combining a risk-free asset with stocks, the investor can achieve an optimal balance between risk and return.

In the Tobin model with a risk-free asset, the so-called "market portfolio line" is constructed – a line connecting the risk-free asset with the efficient stock portfolio. This allows the investor to choose the optimal combination of risk and return depending on their preferences and risk tolerance level (Bagratuni et al., 2023).

Adding a risk-free asset to the portfolio can help reduce the overall risk level, especially during periods of market instability (Kiseleva et al., 2023a; 2023b). The Tobin model with a risk-free asset allows investors to optimally allocate their investments between assets, considering their return, risk, and correlation, ensuring the maximization of expected return for a given risk level or minimizing risk for a given return (Kiseleva et al., 2023c).

Thus, the Tobin model with a risk-free asset is an essential tool in forming a securities portfolio, helping investors make informed decisions when choosing assets for investment and constructing an efficient portfolio.

Minkowski Model

The model of portfolio risk assessment in absolute terms, known as the Minkowski model, is a method of risk analysis in a portfolio that considers the absolute deviations of assets from their expected returns (Urubkov, Fedotov, 2011; Dosugova, 2011; Gubanov, 2014). In the Minkowski model, portfolio risk is measured using metrics based on the sum of absolute deviations (also known as the L1 metric or "Manhattan distance metric"). This differs from the more popular model of portfolio risk assessment in relative terms (coefficient of variation and standard deviation), which measures risk relative to the portfolio return or individual assets (Smirnov et

al., 2024). In the Minkowski model, each asset in the portfolio is weighted by the absolute deviations from their expected returns, and then these sums of modules are added up for all assets in the portfolio. Thus, this method considers both positive and negative deviations from the expected return, making it more resistant to outliers and short-term fluctuations in data. The Minkowski model provides investors with another tool for assessing and managing risk in their portfolios. It can be particularly useful in situations where normal return distribution is not met and when it is necessary to account for possible asymmetries and heavy tails in asset return distributions. Thus, the Minkowski model is an important tool for investors seeking to assess and manage risk in their securities portfolios using absolute deviations from expected returns.

The purpose of this work is to study and apply methods of forming an asset portfolio, considering the optimization of its risks.

Methodologies and Data

In this study, a comprehensive methodology was employed to explore and model decision-making processes under risk conditions. The data for the analysis was gathered from the end-of-month stock prices of four major oil companies – Gazprom Neft, Rosneft, Tatneft, and Lukoil – over the period from November 2022 to November 2023. The methodology involved calculating the returns for each stock using the natural logarithm formula, followed by determining the expected annual returns and risks based on standard deviation. A covariance matrix was then generated using Excel's Solver add-in, allowing for the optimization of the asset portfolio. Three distinct portfolios were created: one with the lowest risk, one with the highest return, and a compromise portfolio balancing both objectives. The study utilized various optimization models including the Sharpe ratio, Markowitz model, Tobin's model, and Minkowski's absolute risk metrics to compare and analyze the effectiveness of different asset allocation strategies.

Results and discussion

Optimizing Portfolio Formation Risks in Practice

Let's try to create a portfolio of various company stocks. We will take the shares of Gazprom Neft, Rosneft, Tatneft, and Lukoil. We will take the price at the end of the month for the last year, i.e., from November 2022 to November 2023 inclusive (Akhmetzyanov, 2023). The data is presented in Table 1.

Table 1. End-of-month stock prices

	End-of-month stock prices			
Month	Rosneft	Tatneft	Gazprom Neft	Lukoil
Nov-22	336,25	366	467,7	4614,5
Dec-22	365,4	348,5	459,5	4069,5
Jan-23	340,75	328,8	441	3955
Feb-23	358,4	328,3	425,85	3990
Mar-23	280,9	373,7	475,15	4352,5
Apr-23	393,8	404	501,1	4674,5
May-23	450,1	443,2	515,2	5569
Jun-23	482,35	505,7	527,95	5079
Jul-23	508,75	523,5	574,25	5938
Avg-23	556,15	590,2	651,75	6830
Sep-23	537	625,4	717,4	6677
Oct-23	574,55	607,6	797,3	7150,5
Nov-23	584,3	638,8	875,1	7239

To further work with the data, it is necessary to calculate the return for each security. Let's assume there are no dividends. We use the natural logarithm formula to calculate the return. Next, we take the average value for the year to calculate the expected return (Table 2). We will calculate the risk using the standard deviation formula.

Table 2. Stock Returns

	Returns			
Month	Rosneft	Tatneft	Gazprom Neft	Lukoil
Dec-22	8,31%	-4,90%	-1,77%	-12,57%
Jan-23	-6,98%	-5,82%	-4,11%	-2,85%
Feb-23	5,05%	-0,15%	-3,50%	0,88%
Mar-23	-24,37%	12,95%	10,95%	8,70%
Apr-23	33,78%	7,80%	5,32%	7,14%
May-23	13,36%	9,26%	2,77%	17,51%
Jun-23	6,92%	13,19%	2,44%	-9,21%
Jul-23	5,33%	3,46%	8,41%	15,63%
Avg-23	8,91%	11,99%	12,66%	14,00%
Sep-23	-3,50%	5,79%	9,60%	-2,27%
Oct-23	6,76%	-2,89%	10,56%	6,85%
Nov-23	1,68%	5,01%	9,31%	1,23%
Expected Return	**4,60%**	**4,64%**	**5,22%**	**3,75%**
Risk	**0,14**	**0,07**	**0,06**	**0,10**

All securities showed positive expected returns. Next, we calculate the covariance matrix between the securities. We use the Solver add-in in Excel. As a result, we get the covariance matrix (Table 3).

Table 3. Covariance Matrix.

	Rosneft	Tatneft	Gazprom Neft	Lukoil
Rosneft	0,017	0,000	-0,001	0,001
Tatneft	0,000	0,004	0,002	0,002
Gazprom Neft	-0,001	0,002	0,003	0,003
Lukoil	0,001	0,002	0,003	0,008

Next, to create a stock portfolio, it is necessary to determine the shares of various stocks that will make up the portfolio. To do this, we use the Solver add-in in Excel. We will create three different portfolios: one with the lowest risk, one with the highest return, and a compromise option. For each option, the portfolio's overall return and risk will be calculated. The portfolio's overall return will be calculated as the sum of the expected return and the share of stocks in the portfolio (Avdiyskiy, 2012; Chernova, Kudryavtsev, 2003; Shapkin, Shapkin, 2014).

Using the Solver add-in in Excel, we enter the cell containing the formula for optimizing the portfolio. In this case, we minimize the portfolio's risk. We will change the stock shares within acceptable constraints: the sum of the stock shares should total 1, and the shares of these stocks should be non-negative. After all the necessary data is entered, we proceed to find the solution. As a result, we get the stock shares, portfolio return, and portfolio risk.

We get a portfolio with the lowest risk (Table 4).

Table 4. Portfolio with the Lowest Risk

	Rosneft	Tatneft	Gazprom Neft	Lukoil
Share	0,165	0,254	0,581	0,000

The total return of this portfolio is 497%. The total risk of this portfolio is 0.047. The portfolio includes shares of three companies out of four; Lukoil shares are not included in the portfolio.

Next, we create a portfolio with the highest return (Table 5).

Table 5. Portfolio with the Highest Return

	Rosneft	Tatneft	Gazprom Neft	Lukoil
Share	0	0	1	0

This portfolio only includes Gazprom Neft shares. The return is 522%. The risk is 0.057.

Next, we create a compromise portfolio. We will search for shares based on maximizing overall return while adding a constraint that the portfolio risk should not exceed 0.05 (Table 6).

Table 6. Compromise Portfolio

	Rosneft	Tatneft	Gazprom Neft	Lukoil
Share	0,137	0,000	0,863	0,000

This portfolio includes Rosneft and Gazprom Neft shares. The total return of this portfolio is 514%. The portfolio risk is 0.05.

As a result, we have obtained three different portfolios for decision-makers with varying levels of risk acceptance.

Conclusion

Studying the optimization of portfolio formation risks is an important and relevant topic in finance and investments. The optimality of an investment portfolio is the most priority task for decision-makers who want to achieve maximum profitability with minimal risks.

When studying the optimization of portfolio formation risks, the main advantages and limitations of various models were identified. It was shown that a well-designed and balanced portfolio can help reduce the overall risk level while maintaining acceptable returns.

Further research in this area may include the analysis of empirical data, the development of new optimization methods, and the application of modern financial instruments to more accurately assess portfolio risks and returns. Optimizing portfolio formation risks remains a complex and important task in the field of investments, and its study continues to be relevant for practitioners and academics.

References

Akhmetzyanov, E. (2023). Maximization of Enterprise Profit in the Perfect Competition Market, In: Collection of Scientific Articles, vol. 16. Chelyabinsk: A. Miller Library Publishing House.

Attekkov, A.V., Zarubin, V.S., Kanatnikov, A.N. (2013). Methods of Optimization: A Study Guide. Moscow: IC RIOR.

Avdiyskiy, V.I. (2012). Risk Management as an Integral Part of Corporate Management System. Accounting, 8, 98–101.

Bagratuni, K., Kashina, E., Kletskova, E., Kapustina, D., Ivashkin, M., Sinyukov, V., Karshalova, A., Hajiyev, H., Hajiyev, E. (2023). Impact of socially responsible business behavior on implementing the principles of sustainable development (experience of large business). International Journal of Sustainable Development and Planning, 18(8), 2481-2488.

Behrens, V., Havranek, P.M. (2005). Guide to Investment Efficiency Evaluation. Moscow: INFRA-M (Interexpert).

Chernova, G.V., Kudryavtsev, A.A. (2003). Risk Management. Moscow: Prospekt.

Damodaran, A. (2004). Investment Valuation. Tools and Techniques for Valuing Any Assets. Moscow: Alpina Business Books.

Degtev, G., Shelygov A., Lizina O., Shichkin I., Kochetkov E. (2022). Impact of Globalization Factors on Inflation Risks During COVID-19 Pandemic. Relacoes Internacionais no Mundo Atual, 4(37), 775–795.

Dementyeva, M.V. (2015). Analysis of Portfolio Management Strategies for Financial Assets. Science Studies, 5(7), 109-122.

Domashchenko, D.V., Finogenova, Yu.Yu. (2010). Risk Management in Financial Instability Conditions. Moscow: INFRA-M.

Dosugova, A.V. (2011). Risk Controlling in the Risk Management System of an Organization. Controlling, 3, 60–63.

Firsova, I.A., Melnik, M.V. (2015). Methods of Managerial Decision-Making. Textbook and Practicum. Moscow: Higher School.

Foss, N.J. (2007). Scientific Progress in Strategic Management: The Case of the Resource-Based View. International Journal of Learning and Intellectual Capital (IJLIC), 4(1/2).

Gibson, R. (2016). Investment Portfolio Formation: Financial Risk Management. Moscow: Alpina Publisher.

Gubanov, R.S. (2014). Insurance of Financial Risks as a Method of Risk Management. Financial Analysis: Problems and Solutions, 8, 31-35.

Ivanyuk, V.A. (2019). Risk Management in Portfolio Investing. Self-Management, 2(2), 340-343.

Khasanov, R.Kh., Savrasova, D.V. (2016). Analysis of Investment Risks in the Russian Securities Market. Sustainable Development of Russia in Unstable Economy Conditions, 281-324.

Khokhlov, N.V. (2003). Risk Management: Study Guide for Universities. Moscow: UNITY-DANA.

Kiseleva, I., Gasparian, M., Karmanov, M., Kuznetsov, V. (2023). Methods of risk assessment and decision-making in investment projects amid economic instability. Journal of Management & Technology, 23(1), 57–68.

Kiseleva, I., Karmanov, M., Kuznetsov, V., & Sadovnikova, N. (2023a). Modeling methods and risk factors in the activities of internet companies. Journal of Management & Technology, 23, 364–377. https://doi.org/10.20397/2177-6652/2023.v23i0.2739

Kiseleva, I., Tramova, A., Gryzunova, N., Romanchenko, O., & Tsetsgee, B. (2023b). Efficient risk assessment and management strategies for economic stability. Journal of Management & Technology, 23, 218–232. https://doi.org/10.20397/2177-6652/2023.v23i0.2660

Kiseleva, I., Tramova, A., Sulumov, S., & Khuriev, R. (2023c). Risk avoidance models as a factor in neutralizing negative consequences. Journal of Management & Technology, 23, 163–173. https://doi.org/10.20397/2177-6652/2023.v23i0.2602

Morrow, J.L., Sirmon, D.G., Hitt, M.A., & Holcomb, T.R. (2007). Creating Value in the Face of Declining Performance: Firm Strategies and Organizational Recovery. Strategic Management Journal, 8(3), 271-283.

Rybakov, A.V., Shichkin, I.A., Tolmachev, O.M., Magomaeva, L. (2022). The Impact of a Progressive Personal Income Tax Scale on Reducing Income Inequality: Comparative Analysis. Relacoes Internacionais no Mundo Atual, 1(34), 371–395.

Shapkin, A.S., Shapkin, V.A. (2014). Risk Theory and Risk Situations Modeling: Study Guide for Bachelor. Moscow: Dashkov and K.

Sharpe, W.F., Alexander, G.J., Bailey, J. (2001). Investments: Textbook. Moscow: INFRA-M.

Smirnov , D., Botasheva , L., Begzadyan, A., Denikaeva, R., Zaikin, V., & Pervyshev, E. (2024). Regulatory and Legal Means and Principles for Regulating Digital Financial Assets and Digital Currencies. REICE: Revista Electrónica De Investigación En Ciencias Económicas, 12(23), 288–297. https://doi.org/10.5377/reice.v12i23.18289

Trofimov, V.V., Trofimova, L.A. (2013). Methods of Managerial Decision-Making. Moscow: Yurayt.

Urubkov, A.R., Fedotov, I.V. (2011). Methods and Models of Optimization in Managerial Decision-Making. Moscow: Delo ANKH.

Watsham, T.J., Parramore, K. (1999). Quantitative Methods in Finance. Moscow: UNITY.