Ding Nan[1], Liu Yanling[2]

RISK ASSESSMENT OF INNOVATION AND INVESTMENT PROJECT IMPLEMENTATION UNDER CONDITIONS OF GROWING UNCERTAINTY IN SUSTAINABLE ENTERPRISE DEVELOPMENT

The article examines a risk-oriented approach to the evaluation and selection of corporate innovation–investment projects amid escalating environmental uncertainty. It is demonstrated that innovation initiatives are future-oriented and, by their very nature, cannot be forecast with precision; therefore, project designers have to account for both uncertainty and risk—two forms of expectation unreliability that differ in the degree to which the probabilities of potential outcomes are known. Despite a substantial body of research in investment analysis, a number of issues (quantitative measurement of uncertainty levels, accurate forecasting of project-efficiency indicators under alternative scenarios, and clarification of the "risk–return" relationship) remain insufficiently elaborated and require methodological refinement. Established quantitative risk-assessment approaches are reviewed—source-based classification, event-tree analysis, expected-return metrics, and historical-data analysis. Particular attention is devoted to indicators derived from the distribution of expected returns: once a probability-distribution curve is constructed, every possible income value is weighted by its probability, yielding a mathematical expectation, while variance and standard deviation serve as the basic measures of risk. The study proves that synthesising the examined methods enhances their advantages and minimises their drawbacks, thereby improving the accuracy and reliability of investment decisions. Further improvement of the risk-management toolkit should combine quantitative simulation techniques with qualitative expert assessments and expand scenario modelling of agent behaviour under uncertainty. The paper provides recommendations that enable enterprises to adjust their portfolio of innovation initiatives in accordance with risk and uncertainty levels and to shape a risk-oriented investment policy using an integrated assessment toolkit. The proposed approaches can be implemented both by individual firms and within government programmes that support innovation activity, ensuring balanced sectoral development in the long term.

Keywords: *risk; uncertainty; innovation–investment projects; return; expectations; planning; forecasting; sensitivity; scenario analysis; sustainable development; enterprise.*

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Лю Яньлін, Дин Нань

ОЦІНКА РИЗИКІВ РЕАЛІЗАЦІЇ ІННОВАЦІЙНО-ІНВЕСТИЦІЙНИХ ПРОЕКТІВ ЗА УМОВ НАРОСТАННЯ НЕВИЗНАЧЕНОСТІ УМОВ СТАЛОГО РОЗВИТКУ ПІДПРИЄМСТВА

Розглянуто ризик-орієнтований підхід до оцінювання та відбору інноваційно-інвестиційних проектів підприємства в умовах наростання невизначеності господарського середовища. Доведено, що інноваційні ініціативи мають віднесення до майбутнього, яке за своєю природою не піддається точному прогнозуванню; отже, розробники проектів змушені враховувати як невизначеність, так і ризик, тобто дві форми ненадійності очікувань, що різняться ступенем відомості ймовірностей можливих наслідків. Відзначено, що попри значний науковий доробок у сфері інвестиційного аналізу,

[1] National Technical University «Kharkiv Polytechnic Institute». Ukraine.
[2] National Technical University «Kharkiv Polytechnic Institute». Ukraine.

низка питань (кількісне вимірювання рівнів невизначеності, точне прогнозування показників ефективності проектів за альтернативних сценаріїв, встановлення взаємозв'язку «ризик-дохідність») залишаються недостатньо опрацьованими й потребують методичного удосконалення. Проаналізовано усталені підходи до кількісного виміру ризику: за джерелами походження, через подієві дерева, за очікуваною доходністю та на основі історичних даних. Особливу увагу приділено метрикам, що ґрунтуються на розподілі очікуваних доходностей: після побудови кривої ймовірнісного розподілу кожне можливе значення доходу зважується на власну ймовірність, що дає математичне очікування, а варіація й стандартне відхилення служать базовими мірами ризику. Доведено, що синтез розглянутих методів дозволяє посилити їхні переваги й мінімізувати недоліки, підвищивши точність та надійність інвестиційних рішень. Відзначено, що подальше вдосконалення методичного апарату ризик-менеджменту має базуватися на поєднанні кількісних імітаційних методів із якісними експертними оцінками та розвитку сценарного моделювання поведінки агентів в умовах невизначеності. Надано рекомендації, які допоможуть підприємствам коригувати портфель інноваційних ініціатив з урахуванням рівня ризику і невизначеності, а також формувати політику ризик-орієнтованого інвестування, використовуючи узагальнений інструментарій інтегрованої оцінки. Обґрунтовані підходи можуть бути імплементовані як в окремих компаніях, так і в державних програмах підтримки інноваційної діяльності, забезпечуючи збалансований розвиток сектору у довгостроковій перспективі.

Ключові слова: *ризик, невизначеність, інноваційно-інвестиційні проекти, доходність, очікування, планування, прогнозування, чутливість, сценарний аналіз, сталий розвиток, підприємство.*

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General statement of the problem and its connection with important scientific or practical tasks. Innovation projects are inherently related to the future, which, by its nature, cannot be predicted with complete certainty. Therefore, the practice of innovation project development necessarily addresses, among other factors, issues of uncertainty and risk.

In this context, uncertainty should be understood as the ambiguous evolution of certain events in the future, the inability to assess the probabilities of potential outcomes, and the challenge of forecasting key indicators of enterprise performance. In contrast, risk is characterized by the presence of known probabilities associated with different possible developments, whereby risk generally refers to the likelihood of an undesirable event occurring. Both uncertainty and risk reflect the unreliability of expectations, as the influence of numerous factors in the implementation of innovation and investment projects is often not precisely determined.

Analysis of recent research and publications. Various aspects of evaluating a company's investment activities under conditions of uncertainty have been examined in the works of Bernus P. [8], Gustafsson R. [9], Hagen B. [5], Hodgson G. [1], Isenberg D. [2], Ketels C. [3], Lim J. [12], Lindqvist G. [3], Marinova D. [4], Miceli A. [5], Nelson R. [6], Ostroverhova G. [7], Phillimore J. [4], Pia Riccardi M. [5], Popov O. [7], Rabelo R. [8], Ritala P. [9], Rogers E. [10], Semenikhin V. [11], Settembre-Blundo D. [5], Solvell O. [3], Sotti F. [5], Vonderembse M. [12], Yudina O. [11], Zhang Q. [12], Zhidik A. [11], Zinchenko G. [11], among others. However, many theoretical and practical issues related to investment decision-making under uncertainty (such as the quantitative assessment of uncertainty levels, forecasting economic indicators of an investment project under various implementation scenarios, establishing the precise relationship between risk and return, and others) remain insufficiently explored and lack comprehensive methodological support.

The article objectives. The purpose of the study is to substantiate and develop recommendations for managing a company's investment activities based on risk assessment during investment decision-making under conditions of uncertainty.

Main part. The analysis and evaluation of innovation projects must, therefore, incorporate considerations of both risk and uncertainty. To address uncertainty, it is proposed to apply methods such as sensitivity analysis, risk analysis, and decision tree analysis.

Sensitivity analysis, for instance, can utilize key indicators such as net present value (NPV) or internal rate of return (IRR). These indicators reflect two essential dimensions of innovation and investment projects: profitability and the associated risk.

The insights gained from sensitivity analysis provide guidance for the planning and control of input variables, as well as the influencing factors. This method is applicable to the evaluation of single-decision models, allowing for an understanding of model structure and the assessment of the impact of unreliable data. By determining the relationship between the profitability of alternatives and input variables, decision-making can be informed based on the results of sensitivity analysis, thus supporting the decision-maker in the selection process.

Moreover, sensitivity analysis enables the identification of critical input variables, making it a valuable tool not only for alternative selection but also for the targeted management of planning and monitoring activities. However, a limitation of the method lies in its assumption of the constancy of non-analyzed variables, which is rarely observed in practice, as most variables are interdependent. Another drawback is the isolated examination of certain input values without consideration of the probability distribution of their deviations. These limitations, however, are largely addressed by the subsequent application of risk analysis.

In risk analysis, it is typical to represent the possible values of unreliable input variables in the form of a probability distribution. For both input and output variables, their probability distributions are determined. Probability distribution can thus be considered a fundamental basis for decision-making under conditions of uncertainty.

Risk analysis encompasses, beyond the evaluation of the decision-making model, additional phases such as the establishment of dependencies and data collection. This method provides a robust framework for decision support; however, it requires the use of digital tools for effective application. One significant difficulty lies in the specification of input data, particularly the definition of probability distributions and stochastic dependencies. Another limitation of risk analysis is that it does not facilitate conclusions about the individual influence of specific input variables on the final outcome. These shortcomings can be addressed through the integration of risk analysis with sensitivity analysis — a combined approach referred to as risk sensitivity analysis.

Within the framework of risk sensitivity analysis, the following elements can be studied: unreliable input variables and their probability distributions, stochastic interdependencies between unreliable inputs, and input variables previously assumed to be reliable.

Another method of risk analysis is scenario analysis, which, alongside the baseline dataset of a project, allows for the consideration of several alternative datasets deemed plausible by project developers. This includes projections for adverse and favorable circumstances. Subsequently, the key investment performance indicator, calculated under good and bad conditions, is compared with the expected value to draw appropriate conclusions for making innovation decisions.

Multistage decision-making problems can be represented through a so-called decision tree. The nodes of the tree represent key events, while the branches connecting the nodes correspond to the project activities or alternative decisions. Additional information, such as timeframes, costs, and the probabilities associated with each decision, is provided. When using decision trees for investment analysis, the expected monetary value (EMV) is commonly employed as the target metric. Under this framework, the optimal decision path is the one yielding the maximum expected monetary value, conditioned on the state of the external environment.

The decision tree method, however, is not without limitations. The complexity of calculations increases significantly as the number of decisions and possible environmental states grows, thus necessitating constraints on the number of considered states. Moreover, expert bias can arise due to the challenges associated with accurately estimating the probabilities of all potential project developments. Additional insights regarding individual input variables can be obtained through sensitivity analysis conducted within the decision tree framework.

The examined methods for accounting for uncertainty in the analysis of innovation and investment projects allow us to conclude that sensitivity analysis and scenario analysis using the decision tree method are particularly applicable.

Risk consideration is one of the fundamental aspects of investment analysis. Its relationship with profitability is reflected in the "golden rule": as expected returns increase, so too does risk. Based on the assessment of investment risk, a comparative evaluation of different securities is conducted, enabling the adoption of an innovative decision and the selection of an investment direction with a level of risk and return acceptable to the investor.

In economic theory and practice, there exist numerous approaches to measuring the magnitude of innovation risk, including: risk assessment by sources of origin, risk assessment through event tree analysis, risk evaluation based on expected returns, and risk evaluation using historical data.

To determine the magnitude of risk based on its sources of origin, a factor model of the income formation process for securities is used. This model accounts for the various factors influencing the return. At the initial stage, factors affecting the return on securities are identified using specific methods and techniques of factor analysis. Subsequently, the sensitivity of the security's return to each factor is determined, and the sensitivity of other securities to the same factors is also calculated. The sensitivity coefficient indicates the strength of the relationship between the security and a given factor and can be utilized for comparative risk analysis among different securities.

A notable limitation of this approach lies in the variability of both the factors themselves and their values across different periods. Nevertheless, this method remains applicable if the investor can construct a reliable forecast of the factors influencing the returns of specific securities.

Risk evaluation through the construction of an event tree is primarily employed for high-risk securities when multiple investment alternatives exist. This approach, however, remains relatively undeveloped in domestic theory and practice. Nevertheless, it is important to note that a security's return, reflected by the magnitude of payouts, simultaneously serves as an indicator of its risk level. Moreover, there are other events that significantly impact the market value, returns, and risk of securities, including changes in interest rates, GDP growth, currency depreciation, and increases in interbank lending rates.

The risk analysis process typically involves the following stages:

1. Identification of possible future events that could affect the returns on financial investments, along with their associated probabilities and outcomes (returns).
2. Construction of an event tree, ensuring that the sum of the probabilities of all subsequent possible events equals one, with all relevant events prior to the project's expiration being accounted for.
3. Calculation of the average expected return, variance, and standard deviation based on the final outcomes of the events. The standard deviation is accepted as the measure of risk.

The primary advantage of this approach is its incorporation of future events into the risk assessment and the resulting risk metric obtained. However, investors must predict future events affecting returns, establish causal relationships among them, and such forecasting is not always feasible due to a lack of reliable information. Furthermore, there is always a danger of subjective judgment, which can reduce the accuracy and quality of the forecasts.

The most common approach to risk assessment is the historical approach, as historical data on returns over several periods is readily available. Risk assessment within this approach proceeds through several stages.

The first stage involves calculating the return on a security over a specified period using a standard formula, depending on the type and characteristics of the particular security. The second stage entails calculating the historical return using either the arithmetic mean or the geometric mean formula. In the third stage, the variance and standard deviation are determined, which characterize the distribution of returns and indicate their deviation from the mean. The greater the deviation, the higher the risk. Using this method, risk is assessed based on historical events. Its advantage lies in the use of objective data, independent of the analyst's opinions and preferences, thus ensuring relatively high accuracy. However, the method also has limitations—past trends cannot be fully extrapolated into the future. In this case, the method evaluates the risk of past investments rather than forecasting the risk of future investments.

Risk measurement based on expected returns involves the use of random variables and the calculation of their characteristics, specifically the expected return and the standard deviation (and sometimes the risk is expressed in concrete monetary loss amounts and their associated probabilities). Initially, a probability distribution curve (either discrete or continuous) of expected returns is constructed. Subsequently, for each expected return, the probability of occurrence is determined. By multiplying each return by its probability and summing the products, the average expected return is obtained. Following this, the variance and standard deviation of the expected value are calculated as measures of risk.

When calculating the standard deviation, no distinction is made between favorable and unfavorable outcomes, that is, between returns above or below the expected average. As a result, the assessment of compensation for risk—specifically, returns exceeding the average—tends to reduce the perceived attractiveness of an innovation.

This aspect is particularly important because the distribution of returns generally does not follow a normal distribution. Therefore, practitioners recommend supplementing the standard deviation with other indicators, such as: the probability of "shortfall" — measuring the likelihood that the return will fall below the expected value; semi-variance — an analogue of variance calculated only on returns below the expected average.

These additional indicators are particularly useful when comparing securities and making decisions regarding acceptable levels of risk.

The standard deviation enables the comparison of securities with identical expected returns, whereas the coefficient of variation is used for analyzing securities with different expected returns, indicating the amount of risk per unit of return. Although the approach to risk assessment based on expected returns is effective, its application presents certain challenges due to the requirement for knowledge of expected return values, and despite the existence of methodologies for their calculation, the reliability of such estimates is not always satisfactory.

Thus, based on the analysis of existing approaches to risk assessment in economic theory and practice, it can be concluded that the advantages of each method can be maximized, and their limitations minimized, only through the justification and synthesis of complementary use of the various methods discussed.

Conclusions. Measuring risk on the basis of expected returns requires treating returns as random variables and calculating their key characteristics—namely, the expected (mean) return and the standard deviation (and, in some cases, expressing risk directly as possible monetary losses and their probabilities). The procedure is as follows. First, a probability-distribution curve (discrete or continuous) of expected returns is constructed. Second, each possible return is paired with its probability of occurrence. Third, multiplying every outcome by its probability and summing the products yields the mean expected return. Fourth, the variance and the standard deviation of that mean are calculated as a measure of risk. When standard deviation is computed, no distinction is made between favourable and unfavourable outcomes—that is, between returns above or below the mean. Consequently, the component of the distribution that represents compensation for bearing risk (returns exceeding the mean) is treated as “risky,” which, in effect, understates the attractiveness of an innovation. This drawback is especially important because empirical return distributions rarely follow the normal law. Practitioners therefore recommend supplementing standard deviation with additional metrics such as: shortfall probability—the likelihood that actual return will fall below the expected level; semi-variance—an analogue of variance that considers only returns below the expected value.

These indicators are particularly useful when comparing securities and deciding what level of risk is acceptable. Standard deviation is appropriate for comparing securities that share the same expected return, whereas for instruments with different expected returns analysts employ the coefficient of variation, which shows the amount of risk per unit of return.

Although the "expected-return" approach to risk assessment is conceptually sound, its practical use is complicated by the need for reliable estimates of expected returns; existing estimation techniques do not always yield sufficiently accurate figures.

Accordingly, a review of theoretical and practical methods suggests that their strengths can be enhanced and their shortcomings mitigated only through a well-grounded synthesis and mutually complementary application of the techniques described above.

Future research in this field will focus on developing methodological approaches for scenario-based modelling of agent behaviour strategies under conditions of uncertainty.

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