

SECTION 19

PHYSICAL AND MATHEMATICAL SCIENCES

УДК 519.21:330.4

Yarova O. A.

PhD in Physical and Mathematical Sciences, Associate Professor, Head of the Department of Higher and Applied Mathematics, Faculty of Finance and Digital Technology, State Tax University, Ukraine
<https://orcid.org/0000-0002-0522-8368>

THE ROLE AND APPLIED POTENTIAL OF PROBABILITY THEORY IN MODELING ECONOMIC UNCERTAINTY

The specificity of the functioning of the modern economy lies in the fact that most managerial and financial decisions are made under conditions of significant uncertainty. The final performance results of enterprises are substantially influenced by unpredictable fluctuations in market prices, exchange rate volatility, changes in interest rates, or shifting consumer demand capacity. In this context, the key task for an analyst is not merely forecasting potential outcomes, but providing a formalized assessment of their likelihood, for which the apparatus of probability theory is utilized [1; 2].

As a fundamental mathematical discipline, probability theory studies the patterns of random phenomena and offers a toolkit for a rigorous quantitative description of risky situations. Its principles find application in economic analysis, corporate finance, actuarial science, and management – wherever the factor of randomness plays a crucial role [1; 2; 4; 6].

The formation of probability theory is historically linked to the first attempts to systematize and mathematically describe mass random events. The foundation of this field was laid by the works of B. Pascal, P. Fermat, C. Huygens, and P. Laplace, whereas the concept acquired modern mathematical rigor thanks to the axiomatization by A. N. Kolmogorov. It was precisely this axiomatic foundation that made it possible to adapt probabilistic modeling for solving large-scale practical problems [1; 2; 6].

The central category for economic and financial research is the *random event*. In practical terms, it is understood, for instance, as an increase in stock value over a certain period, an exchange rate jump exceeding a

specified level, or a company achieving its target profit. For the banking sector, a borrower's default represents a critically important random event, while in the insurance business, it is the actual occurrence of an insured event.

The implementation of a probabilistic model allows a transition from the descriptive judgment "an event is possible" to its measurable value. While information about a potential rise or fall in asset value is valuable in itself, calculating the probabilities of each scenario and evaluating the associated losses enable the formation of a comprehensive risk profile [3; 4].

In the analytical process, it is also expedient to consider *complementary events*. If event A denotes the successful execution of a financial plan, then the complementary event $\bar{A}$ signifies failure to achieve it. By comparing the probabilities of these two states, the analyst gains the ability to simultaneously assess both optimistic and adverse courses of events [1; 2].

Modern risk management systems are built upon this logic: a bank calculates the probability of loan default to form appropriate reserves; an investor focuses on the balance between expected return and potential losses; an actuary relies on the frequency of insured events when calculating premium rates.

The category of *mutually exclusive (disjoint) events* is also of significant importance. For example, within a single model, the trajectory of a specific financial indicator cannot simultaneously exhibit both growth and decline. Defining such events as mutually exclusive eliminates contradictory results during scenario building [1; 2].

When the set of available outcomes covers absolutely all possible consequences of a given situation, it forms a *collectively exhaustive set of events*. In particular, when assessing the prospects of a company's financial condition, three baseline scenarios are typically defined: growth, stabilization, or decline in performance indicators. The probability distribution across these scenarios provides a holistic view of the system's future state.

Under the classical definition of probability, if all elementary outcomes are equally likely, the probability of event A is given by:

$$P(A) = \frac{m}{n},$$

where m is the number of outcomes favorable to A , and n is the total number of equally likely outcomes [1; 2].

However, for real economic processes, the classical definition is rarely suitable due to the difficulty of satisfying the "equally likely" requirement. Most frequently, researchers rely on the statistical approach. By analyzing historical time series (for instance, the default rate among borrowers of a

specific category), the researcher determines the empirical frequency of the event, which serves as a benchmark for future risks [2; 3].

In a geometric probability model, assuming a uniform distribution over the sample space Ω , the probability of an event A is defined as

$$P(A) = \frac{\mu(A)}{\mu(\Omega)},$$

where $\mu(A)$ is the measure of the region corresponding to event A , and $\mu(\Omega)$ is the measure of the entire sample space. Depending on the dimension of the problem, the measure may represent length, area, or volume (fig. 1).

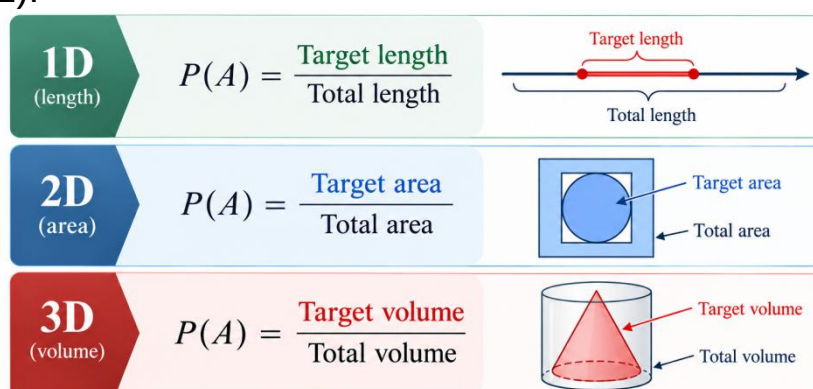


Fig.1. Geometric probability models

By definition, the probability of any event A satisfies:

$$0 \leq P(A) \leq 1.$$

A value of $P(A)$ close to 1 indicates a high likelihood of the event, whereas a value close to 0 represents an unlikely scenario. For the complementary event, the following relationship holds:

$$P(\bar{A}) = 1 - P(A).$$

Thus, if the estimated probability of a financial risk event is 0.2, the probability of its complement is 0.8, allowing the risk to be expressed as a precise numerical value.

The synthesis of probabilistic models with mathematical statistics methods opens up opportunities for detecting hidden patterns in datasets, conducting regression analysis, and building sound economic forecasts [2; 3; 5].

The analysis demonstrates that the practical value of probability theory in economics lies not merely in describing random phenomena but in transforming uncertainty into quantitatively measurable risk. Classical, empirical, and geometric probability models provide complementary approaches to formalizing uncertain economic situations, while the concepts of complementary, mutually exclusive, and exhaustive events

enable the systematic construction of financial scenarios. This framework provides a mathematical basis for risk assessment and supports more informed decision-making in finance, banking, insurance, and business analytics.

References

1. Zhluktenko, V. I., & Nakonechnyi, S. I. (2000). *Teoriia ymovirnostei i matematychna statystyka. Ch. 1. Teoriia ymovirnostei* [Theory of probability and mathematical statistics. Part 1. Theory of probability]. Kyiv: KNEU.
2. Ohirko, O. I., Halaiko, N. V. (2017). *Teoriia ymovirnostei ta matematychna statystyka* [Theory of probability and mathematical statistics]. Lviv: Lviv State University of Internal Affairs.
3. Bilotserkivskyi, O. B. (2018). *Teoriia ymovirnostei i matematychna statystyka* [Theory of probability and mathematical statistics]. Kharkiv: NTU "KhPI".
4. Vasylchenko, I. P. (2004). *Vyshcha matematyka dlia ekonomistiv (spetsialni rozdily)* [Higher mathematics for economists (special sections)]. Kyiv: Kondor.
5. Zhelezniakova, E. Yu., Norik, L. O. (2019). *Teoriia ymovirnostei ta matematychna statystyka* [Theory of probability and mathematical statistics]. Kharkiv: Simon Kuznets Kharkiv National University of Economics.
6. Brianska, Y. O., Yarova, O. A. (2024). Vnesok ukrainskykh naukovtsiv v rozvytok teorii ymovirnosti [Contribution of Ukrainian scientists to the development of probability theory]. *Scientific Collection "InterConf"*, 2024, P. 122–126.