No: 03 2025
https://doi.org/10.64400/ea25-3-21
ISSN 2224-5529 2224-0829 2223-5124 2222-940X

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UNİVERSİTETİNİN
ELMİ ƏSƏRLƏR JURNALI

THE İMPORTANT ROLE OF PROBABİLİTY THEORY AND MATHEMATİCAL STATİCS İN THE DEVELOPMENT OF FİNANCİAL AND İNVESMENT ANALYSİS

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NƏŞR TARİXİ:
Qəbul edilmə tarixi: 08.09.2025
Nəşr edilmə tarixi: 28.10.2025

AÇAR SÖZLƏR:
Probability theory, Mathematical statistics, Financial analysis, İnvestment decisions, Risk management, Stochastic models

XÜLASƏ

This article examines the importance of probability theory and mathematical statistics in financial and investment analysis. Probability theory supports financial decision-making under uncertainty, determines the risk-return relationship of assets, and is applied in approaches such as Markowitz portfolio theory and the Black-Scholes model. Mathematical statistics, on the other hand, play an important role in the analysis, forecasting, and risk management of financial markets. Models such as ARIMA, GARCH, and VAR are used to analyze market volatility. Probability theory and statistical methods play a key role in risk management, with the VAR method in particular being widely used. Consequently, research and development in these areas ensures that financial decisions are more accurate and effective.

İNTRODUCTION

Financial and investment analysis is one of the most important directions of modern economy. This field largely involves decision-making under conditions of uncertainty. In this regard, probability theory and mathematical statistics play an indispensable role in the study of financial markets, in the optimization of investment decisions and in risk management. In this article, how probability theory and mathematical statistics are applied in financial and investment analysis, the main models and approaches used in this field will be examined in detail.

The Role of Probability Theory in Financial and Investment Analysis

Probability theory plays a fundamental role in financial and investment analysis, providing a mathematical framework for modeling uncertainty, assessing risk, and optimizing decision-making in financial markets. The inherent volatility of financial instruments, coupled with unpredictable economic conditions, makes probabilistic methods essential for risk management, portfolio optimization, and the valuation of financial derivatives.

By utilizing probability distributions, stochastic processes, and statistical inference, financial analysts can quantify uncertainties and develop models that assist investors in making informed decisions. The following sections explore three major areas where probability theory significantly influences financial and investment analysis: the relationship between risk and return, Markowitz portfolio theory, and option pricing models.

1. The Relationship Between Risk and Return

In the world of finance, the relationship between risk and return is a key issue. Probability distributions, including the normal distribution, log-normal distribution, Poisson processes, and other statistical methods are used to measure this relationship. In portfolio management and the insurance market, probability theory is used to assess risks.

2. Markowitz Portfolio Theory

Harry Markowitz's Modern Portfolio Theory (MPT) is one of the most important applications of probability theory in finance. It emphasizes the importance of diversification to reduce risk while maintaining optimal returns.

In MPT, an investment portfolio consists of multiple assets, each with its own expected return and risk. The return of a portfolio is given by:

$$E[R_p] = \sum_{i=1}^{n} w_i E[R_i]$$

Here:

- $E[R_p]$ is the expected return of the portfolio.
- w_i is the weight of asset i in the portfolio.
- $E[R_i]$ is the expected return of asset i.

The variance (risk) of the portfolio is computed using:

$$\sigma_p^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \sigma_{ij}$$

3. Option Pricing Models

Options and other financial derivatives rely on probability theory to determine their fair value. The pricing of options involves stochastic processes, such as Brownian motion and Geometric Brownian Motion (GBM), which model the random movement of asset prices.

The **Black-Scholes Model** is the most widely used formula for pricing European options. It is based on the assumption that stock prices follow a log-normal distribution and that their returns are normally distributed. The Black-Scholes equation is given by:

$$C = S_0 N(d_1) - X e^{-rT} N(d_2)$$

Here:

- C is the call option price.
- S_0 is the current stock price.
- X is the strike price.
- r is the risk-free rate.
- T is the time to expiration.
- $N(d)$ represents the cumulative probability of the standard normal distribution.

The probabilities used in the Black-Scholes model are derived using risk-neutral valuation, a probability-based technique that assumes all investors are indifferent to risk when pricing derivatives.

Monte Carlo Simulations in Option Pricing

Monte Carlo simulations, another application of probability theory, are used to estimate the price of complex derivatives. These simulations involve generating thousands of possible future price paths for an asset and computing the expected payoff of the option. This probabilistic approach is especially useful for pricing exotic options and structured financial products.

Application of Mathematical Statistics in Financial and Investment Analysis

Mathematical statistics plays a crucial role in financial and investment analysis by providing tools for data-driven decision-making, risk assessment, and predictive modeling. Financial markets generate vast amounts of data, and statistical methods help in extracting meaningful insights, detecting trends, and managing uncertainty. Three major applications of mathematical statistics in finance include time-varying models, statistical data analysis, and machine learning with big data analytics.

1. Time-varying Models

Understanding Financial Market Dynamics

Financial markets are inherently dynamic, with asset prices, interest rates, and volatilities fluctuating over time. To model these variations, statistical techniques such as time series analysis are widely employed. These models capture past patterns and use them for forecasting and risk assessment.

Autoregressive Integrated Moving Average (ARIMA) Models

ARIMA models are fundamental in time series forecasting. They combine:

- **Autoregressive (AR)** terms, which incorporate past values.
- **Moving Average (MA)** components, which include past forecast errors.
- **Integration (I)**, which accounts for trends in the data.

The general form of an ARIMA model is given by:

$$Y_t = c + \sum_{i=1}^{p} \phi_i Y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t$$

Generalized Autoregressive Conditional Heteroskedasticity (GARCH) Models

GARCH models help in forecasting financial market volatility by modeling conditional variance. Since financial returns often exhibit volatility clustering (periods of high or low volatility persisting over time), GARCH models are highly useful for risk management and derivative pricing. The standard GARCH(1,1) model is defined as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

Vector Autoregression (VAR) Models

VAR models are widely used to analyze multiple time-dependent financial variables simultaneously, such as stock returns and interest rates. A VAR model with two variables X_t and Y_t can be expressed as:

$$X_t = c_1 + \phi_{11} X_{t-1} + \phi_{12} Y_{t-1} + \varepsilon_{1t}$$
$$Y_t = c_2 + \phi_{21} X_{t-1} + \phi_{22} Y_{t-1} + \varepsilon_{2t}$$

2. Statistical Analysis of Data

Hypothesis Testing and Inference in Financial Decision-Making

Statistical hypothesis testing is widely used to validate financial theories and detect anomalies in asset pricing. Key techniques include:

- **t-tests** for comparing means (e.g., checking whether a stock's return is significantly different from zero).
- **ANOVA (Analysis of Variance)** for comparing multiple financial assets.
- **Chi-square tests** for categorical data analysis in market behavior studies.

Regression Analysis in Financial Markets

Regression analysis is a cornerstone of statistical modeling in finance, helping to establish relationships between variables.

- **Simple Linear Regression** is given by:

$$Y = \beta_0 + \beta_1 X + \varepsilon$$

- **Multiple Regression** models are useful in explaining asset returns based on multiple factors, such as economic indicators and firm-specific attributes.
- **Logistic Regression** is used for classification problems, such as predicting market crashes or corporate defaults.

3. Machine Learning and Big Data Analytics

In recent years, mathematical statistics and machine learning methods have been increasingly used in financial and investment analysis. Artificial intelligence and big data analysis have become key research areas for banks, stock exchanges, and investment funds.

The Importance of Probability and Statistics in Risk Management

Risk management is one of the main applications of probability theory and mathematical statistics. Banks and other financial institutions use statistical models and probability methods to reduce their risks. One of the main approaches to risk assessment is the VaR (Value at Risk) method. This method estimates the possible losses of a portfolio based on probability distributions.

CONCLUSION

Probability theory and mathematical statistics play an important role in the field of finance and investment. Their application helps to deeply analyze financial markets, manage risk, and optimize investment strategies. In the future, new research in these areas, the development of probability models and statistical methods will create conditions for more sustainable and effective decision-making in the financial world.

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XÜLASƏ

MALİYYƏ VƏ İNVESTİSİYA ANALİZİNİN İNKİŞAFINDA EHTİMAL NƏZƏRİYYƏSİ VƏ RİYAZİ STATİSTİKANIN MÜHÜM ROLU

Rəhimə Sadiqova

Bu məqalə maliyyə və investisiya analizində ehtimal nəzəriyyəsi və riyazi statistikanın əhəmiyyətini araşdırır. Ehtimal nəzəriyyəsi qeyri-müəyyənlik şəraitində maliyyə qərarlarının qəbulunu dəstəkləyir, aktivlərin risk və gəlir münasibətini müəyyən edir, Markowitz portfel nəzəriyyəsi və Black-Scholes modeli kimi yanaşmalarda tətbiq olunur. Riyazi statistika isə maliyyə bazarlarının təhlili, proqnozlaşdırılması və risklərin idarə olunmasında mühüm rol oynayır. ARIMA, GARCH və VAR kimi modellər bazar dəyişkənliyini analiz etmək üçün istifadə olunur. Riskin idarə olunmasında ehtimal nəzəriyyəsi və statistik metodlar əsas rol oynayır, xüsusilə də VAR metodu geniş tətbiq olunur. Nəticə etibarilə, bu sahələrdə tədqiqat və inkişaf maliyyə qərarlarının daha dəqiq və effektiv olmasını təmin edir.

Açar sözlər: Ehtimal nəzəriyyəsi, riyazi statistika, maliyyə analizi, investisiya qərarları, risk idarəetməsi, stokastik modellər, Markowitz portfel nəzəriyyəsi, Black-Scholes modeli.