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УДК 811.111

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MATHEMATICAL METHODS AND INFORMATION TECHNOLOGIES IN FINANCE

У цій статті досліджується конвергенція кількісних математичних методів та передових інформаційних технологій у сучасних фінансах. Вона зосереджена на застосуванні моделей оптимізації, машинного навчання та високопродуктивних обчислень для покращення управління ризиками та ринкової ефективності в рамках глобальної цифрової економіки.

Ключові слова*: математичне моделювання, фінансова інженерія, інформаційні технології, машинне навчання, оптимізація портфеля, управління ризиками, фінтех, великі дані, блокчейн, кількісні фінанси.*

This paper explores the convergence of quantitative mathematical methods and advanced information technologies in modern finance. It focuses on the application of optimization models, machine learning, and high-performance computing to enhance risk management and market efficiency within the global digital economy.

Keywords: *Mathematical modeling, Financial engineering, Information technologies, Machine learning, Portfolio optimization, Risk management, FinTech, Big Data, Blockchain, Quantitative finance.*

Introduction. This paper explores the convergence of quantitative mathematical methods and advanced information technologies in modern finance. It focuses on the application of optimization models, machine learning, and high-performance computing to enhance risk management and market efficiency within the global digital economy.

Keywords: Mathematical modeling, Financial engineering, Information technologies, Machine learning, Portfolio optimization, Risk management, FinTech, Big Data, Blockchain, Quantitative finance.

Finance has changed drastically in recent years, moving away from a reliance on human intuition toward a highly quantitative, data-driven discipline. At the core of this shift is Quantitative Finance—the combination of advanced mathematical modeling and modern information technology. This approach allows institutions to manage massive capital flows with unprecedented accuracy. In this context, mathematics provides a framework to measure and understand uncertainty, while IT translates these theoretical models into actual, real-time market operations [2]. The ability to quantify probability has turned financial speculation into a structured engineering problem.

A major focus of mathematical finance is optimizing portfolios under risk. Modern Portfolio Theory, for example, uses quadratic programming and linear algebra to find the "efficient frontier," helping investors maximize returns for a specific level of risk. Beyond static models, stochastic calculus and differential equations are now essential for pricing complex derivatives. By treating asset price movements as continuous random walks (Brownian motion), analysts can fairly price options using models that protect market participants from extreme volatility [2]. Additionally, risk metrics like Value at Risk (VaR) and Conditional Value at Risk (CVaR) have become standard industry requirements. These tools allow banks to simulate thousands of market scenarios to ensure they keep enough capital on hand to survive potential market crashes.

Of course, applying these complex equations wouldn't be possible without modern IT infrastructure. The financial sector now relies on high-performance computing systems that process massive datasets in milliseconds. This technology automates everything from high-frequency trading (HFT) to everyday banking operations. In HFT, for instance, algorithms execute trades based on mathematical arbitrage opportunities that exist for only a fraction of a second [5]. While the shift to digital platforms has sped up capital flows and increased market liquidity, it has also forced the industry to develop much stronger cybersecurity measures. Information technology must now not only process trades but also protect financial assets from increasingly sophisticated digital perils and systemic failures [1].

Artificial Intelligence (AI) and Machine Learning (ML) are currently pushing the boundaries of what is possible in finance. Unlike older econometric models that often rely on rigid linear assumptions, deep learning networks and random forests can spot hidden, non-linear patterns in historical data that humans might overlook. This makes ML incredibly useful for modern credit scoring, automated wealth management (robo-advisors), and real-time fraud detection, where it routinely outperforms traditional statistical approaches [3]. Furthermore, the proliferation of distributed IT structures, such as blockchain, is altering the very concept of trust in finance. By using cryptographic proofs instead of central authorities, these systems permit transparent, direct trades without the need for traditional middlemen or expensive clearinghouses.

Ultimately, bringing together strict mathematical methods and high-performance computing has made the financial sector much more efficient, but also far more complex. The interconnectedness of global markets means that a small error in an algorithm can have widespread consequences. Looking ahead, emerging technologies like quantum machine learning for time-series forecasting could completely change how we process financial data and solve optimization problems [4]. To succeed in this field today, professionals need a dual mastery: the mathematical acumen to build complex models and the technical expertise to deploy them within a global, digitally-focused infrastructure.

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