The Application of Economic Mathematics in the Field of Financial Economics

Bohan Jia
Shenyang Bopai Trading Co., Ltd., Shenyang, China
747946667@qq.com

Abstract. This paper discusses its application in the field of financial economics from the connotation and methods of economic mathematics, focusing on risk management, portfolio optimization, financial derivatives pricing and macroeconomic forecast analysis. By expounding specific application examples in economic mathematics such as probability statistics, optimization theory, and stochastic processes in the above fields, its unique role in providing quantitative analysis tools is revealed. This paper provides institutional support for scientific understanding and guidance of policies and operations of financial and economic activities, aiming to highlight the close connection between economic mathematics and financial and economic practice and its good application prospects.

Keywords: Economic mathematics; finance and economics; risk management; portfolio.

1. Introduction

With the sustainable development of the market economy, the economic phenomenon has become more and more complex and changeable. In such an environment, the competitive pressure faced by the market economy is increasing, which poses a direct threat to the survival and development of enterprises. If this development trend cannot be effectively controlled, it will inevitably have a negative impact on the survival and development of enterprises. Therefore, we need to conduct in-depth research on the development trend of the market economy in order to formulate appropriate countermeasures.

In terms of economic analysis, the traditional analysis model can no longer meet the needs of the current new market. In order to better promote the development of the market economy, it is necessary to design a very reasonable analysis model to replace the existing economic analysis methods, so as to conduct a more accurate and comprehensive analysis of the financial economy, and then promote its healthy and stable development. As an analytical method that focuses on quantitative changes, economic mathematics can organically combine qualitative and quantitative methods to comprehensively analyze specific problems in the financial field, and its theoretical scope includes limit theory, differential equations, etc., which can simplify complex economic phenomena into intuitive mathematical models. In this way, relevant personnel can deal with complex financial and economic issues more conveniently, so as to provide strong support for the development of the market economy. Therefore, in the field of financial economics, it is necessary to increase the frequency of application of economic mathematics to deal with various complex economic problems [1]. In this context, this paper intends to explore the application of economic mathematics in the field of financial economics, hoping to help enterprises better cope with the complexity and variability of economic phenomena and help them better cope with various challenges.

2. The Necessity and Method of Applying Economic Mathematics in the Field of Financial Economics

2.1. The Necessity of the Application of Economic Mathematics in the Field of Financial Economics

Complex financial and economic activities contain randomness, dynamics and uncertainty, which bring challenges to the decision-making and risk control of economic agents. This requires the use of quantitative models and algorithms to depict and grasp the laws of finance and economics. Economic mathematics is the discipline that provides these powerful tools, and the necessity of its application in the field of financial economics is reflected in the following.

Firstly, economic mathematical methods can provide an in-depth description of the intrinsic mechanisms of the price and risk of financial assets. For example, Markowitz's portfolio theory uses mathematical language to clarify the return-risk attributes of multiple asset portfolios. The GARCH model family reveals the time-varying volatility of financial asset returns. This provides a basis for decision-making by investors and risk managers.

Secondly, the quantitative model established by economic mathematics enables complex financial and economic problems to be formalized in computer language and supports the optimization of decision-making. For example, the Black-Scholes option pricing model transforms the option pricing problem into solvable partial differential equations. This makes trading and risk management of financial derivatives possible.

Thirdly, the combination of economic mathematics and computational methods drives more granular and real-time financial and economic forecasting. For example, machine learning algorithm models can learn the connections of financial variables from massive information to achieve high-precision and comprehensive prediction of financial time series or cross-variable data. This is beneficial for both financial regulation and investment decisions.

2.2. Methods of Application of Economic Mathematics in the Field of Finance and Economics

As a branch of applied mathematics, economic mathematics has a rich and diverse methodological system. According to different research needs, economic mathematics can use various mathematical tools such as calculus, linear algebra, probability theory, optimization theory, and game theory for modeling and analysis. Among them, calculus methods are mostly used to depict the growth trend of economic variables, such as the C-D production function in the economic growth model. Linear algebra is convenient for expressing complex dependencies between multiple variables and establishing input-output models. Probability theory and statistical methods emphasize randomness and can deeply simulate uncertain economic problems such as financial risks. At the same time, many modern mathematical theories also provide new analytical perspectives for economic mathematics. For example, operations research methods support the optimization of decision-making, information theory clarifies the impact of information on economic activities, graph theory captures the network dependence effect between variables, and interval analysis integrates the identification and control of uncertainty. In recent years, the integration of economic mathematical models and algorithmic methods has also become an important trend. Machine learning algorithms realize intelligent analysis of massive economic data, bringing higher accuracy to economic forecasting and decision-making. At the same time, the framework of computational economics also promotes the organic combination of economic theory and numerical simulation methods. It can be said that economic mathematics, as a highly applied interdisciplinary discipline, not only includes traditional mathematical analysis tools, but also continues to learn from the innovation of modern mathematical methods, and achieves deep integration with computing methods. This provides the possibility to describe and guide the continued development of economic activity [2].

3. The Application of Economic Mathematics in the Field of Finance and Economics

3.1. Risk Management: Use Probability Theory and Statistical Methods for Risk Assessment and Prediction

The complex and changeable financial market exposes various economic entities to huge asset price fluctuation risks and market liquidity risks. This requires the use of probabilistic statistics and stochastic process theory for risk identification, assessment and prediction.

Financial risk management is a crucial part of modern finance, aiming to ensure that financial institutions, enterprises, and investors can effectively respond to potential risks in the face of changing market conditions. Advanced financial risk management methods are mainly based on the modeling of market random fluctuation mechanisms, which can help us better understand and predict the volatility of financial markets, thereby providing powerful tools for risk management.

Firstly, the VaR and CVaR models measure the likelihood of extreme losses from a probability distribution perspective. The parameters of these models can be fitted by distribution function using the central limit theorem, and can also be estimated by using Hill estimation and other methods to improve the prediction accuracy of the probability of extreme events. Secondly, the Monte Carlo simulation method based on stochastic process theory has been widely used in derivatives pricing and risk exposure calculation. This method can reveal the evolution characteristics of return risk in the time dimension by simulating stochastic processes, thereby providing support for risk management. At the same time, Monte Carlo simulation can also combine big data and artificial intelligence technology to further improve model recognition capabilities and facilitate real-time updates, making financial risk management more efficient and accurate [3,4].

Overall, through the continuous optimization and integration of various risk models, combined with big data and artificial intelligence technology, we can more accurately predict and prevent financial risks and escort the steady development of the financial market.

3.2. Portfolio Optimization: Construct the Optimal Portfolio through Mathematical Modeling and Optimization Methods

The goal of portfolio optimization is to choose the optimal asset allocation ratio that balances risk and return under the premise of a given risk tolerance. Its methodological basis is modern portfolio theory. This theory uses a mathematical optimization model to describe the relationship between asset allocation and risk-return, so as to find the optimal solution.

Firstly, it is necessary to establish a mathematical portfolio optimization model, such as a single-index model and a multi-factor model that can describe securities pricing from different dimensions. The CAPM model, which is based on the market benchmark portfolio as the independent variable, reveals the impact of systemic risk on asset returns. These models define clear objective functions, decision variables, and constraints. Secondly, the algorithms such as linear programming, quadratic programming, and stochastic optimization in mathematical optimization theory can be used to solve the model. These algorithms support multi-dimensional iteration and rapid optimization of combinatorial weights or other decision variables under the premise of ensuring the optimization goal. Heuristics such as the Stillwater algorithm can also be used to solve large-scale complex portfolio problems.

It can be said that the quantitative model and optimization algorithm of economic mathematics realize the simulation of complex and uncertain financial markets, and guide investment practice based on scientific rationality, which has greatly promoted the development of modern investment management from pure empiricism to automation and quantification. They also put investment in this high-risk area under a controllable mathematical, physical and chemical framework [5,6].

3.3. Financial Derivatives Pricing: Calculus and Stochastic Process Theory are Used to Price Derivatives

As an important type of financial engineering product, the value of financial derivatives depends on the price or income of an underlying asset. The difficulty of derivatives pricing is how to describe the complex random underlying asset price and value complex financial engineering modeling based on this.

In this regard, the theory of differential equations and stochastic differential equations in economic mathematics gives effective methods. Specifically, in derivatives pricing, differentiation is used to calculate the impact of small changes in the price of the underlying asset on the value of derivatives. By calculating the instantaneous yield and volatility of the underlying asset, the theoretical price of the derivative can be determined. For example, the Black-Scholes option pricing model, a stochastic differential equation based on the price of the underlying asset, is transformed into a partial differential equation that describes the change in the price of an option. This equation has an analytical solution that directly calculates the theoretical price of the option. This provides a theoretical basis for trading and risk management of derivatives such as options. Another example is the Kultureinricht-Markov (KW-MK) model in stochastic calculus theory, which is also widely used to simulate the description of underlying assets such as interest rates or exchange rates. Combined with the Monte Carlo method, random sampling and pricing tests can be repeatedly conducted on the price path of the underlying asset, the price and risk level of derivatives can be comprehensively evaluated, and stress tests can be conducted.

In the big system of economic mathematics, integral is also an indispensable component. Integrals can be used to describe phenomena in economics in a concrete way. In economics, there is a concept called economic surplus, which includes consumer surplus, producer surplus and the total surplus of both, and the total surplus and consumer surplus are often used as a measure of social and economic welfare. The calculation of economic surplus often requires the relevant knowledge of integrals, and the quantitative analysis of functions is carried out to obtain data to measure social and economic welfare. For example, in the process of selling a certain commodity, the area formed between the buyer’s willingness to pay and his actual payment amount is the consumer surplus, which can be calculated by a fixed integral. The area between the lowest price that producers are willing to sell and the actual selling price can also be calculated by using fixed integrals, and social and economic benefits can be obtained by summing these two areas. The accurate calculation of social and economic welfare is of great significance to maintaining stable economic development.

In summary, calculus and stochastic process mathematical tools provide the possibility to extract the deterministic trend and stochastic fluctuation components of the price movement of the underlying asset. Based on this, complex derivative financial products can also be discounted and priced, so as to achieve scientific risk management. This helps to promote the rapid development of the financial derivatives market.

3.4. Macroeconomic Forecast Analysis: Use Economic Mathematical Models to Predict Economic Indicators and Policy Effects

The complex global macroeconomic operation contains a large number of uncertain influencing factors, which poses challenges to policy-making. Establishing economic mathematical models for macroeconomic analysis is an important way to deal with this problem. The DSGE model family in mainstream macroeconomics uses differential equations to describe the interaction mechanism of various fields of economics. This type of model incorporates the characteristics of neoclassical theory and Keynesian theory to support a unified simulation of short-term equilibrium and long-term growth. They are widely used to predict future movements in core economic indicators such as GDP, inflation rates, and unemployment rates. In addition, policy simulation based on economic mathematical models has also become an important means to evaluate the effect of decision-making. For example, by changing the parameter setting of the model, the impact of tax rate adjustment on employment and price levels is simulated, or test the dynamic path of GDP change at different levels of fiscal spending. This provides policymakers with the tools to quantitatively identify the optimal level of policy.

At the same time, with the rapid development of science and technology, big data and artificial intelligence technology are increasingly widely used in various fields. In the field of economics, the use of these advanced technologies for macroeconomic forecasting and policy evaluation has become an inevitable trend in future development. Models enhanced by deep learning are expected to play an important role in economic forecasting and policy evaluation, providing strong support for our country's economic development. For example, compared with traditional economic forecasting methods, deep learning technology can automatically extract data features and mine potential laws, thereby better coping with the complexity and uncertainty of economic data. By constructing a macroeconomic forecasting model enhanced by deep learning, various economic indicators can be accurately predicted, providing a strong basis for policymakers [7,8].

4. The Trend of Economic Mathematics Applied to Financial and Economic Analysis

In today's increasingly developed and complex financial market, people's requirements for financial data analysis and prediction are also getting higher and higher, and economic mathematics has become an indispensable tool for financial and economic analysis due to its accurate and rigorous theoretical foundation and strong computing power.

Firstly, with the rapid development of big data, artificial intelligence and other technologies, the processing and analysis of data in economic mathematics will also be used at a deeper level. Massive financial data needs to be processed and refined with the help of statistical analysis and data mining in economic mathematics to find out the hidden laws and tendencies behind it. At the same time, the integration of economic mathematics and artificial intelligence technology will also make financial market forecasting and risk management smarter and more accurate.

Secondly, financial engineering is an important application direction of economic mathematics in the financial field and will continue to develop. Financial engineering uses mathematics, statistics, computer technology and other knowledge to realize the design, pricing and risk management of financial products, so as to provide more effective and accurate financial services for financial institutions and investors. With the continuous innovation and development of the financial market, financial engineering will play a more important role in financial and economic analysis.

Thirdly, with globalization and the interconnection of financial markets, economic mathematics will be widely used in transnational financial analysis and risk management. Cross-border financial transactions cover economic, political and cultural elements of various countries and regions, and need to be analyzed and predicted with the help of economic mathematics and econometrics, as well as the theories and methods of international finance. At the same time, economic mathematics also helps financial institutions to assess and manage cross-border financial transactions to ensure the stable and healthy development of financial markets.

5. Summary

After the above analysis, it can be concluded that economic mathematics plays an increasingly important role in the field of modern finance and economics. The quantitative models and analysis methods provided by economic mathematics enable complex financial and economic phenomena (such as price fluctuations of financial assets, risk contagion, etc.) to be described in scientific language and support rational prediction and management. Specifically, in key areas such as financial risk assessment and control, portfolio optimization, financial derivatives pricing, and macroeconomic operation forecasting, economic mathematical methods have shown strong explanatory ability, guiding significance and application value. This provides strong technical support for financial regulatory authorities to formulate policies, investment institutions to make asset allocation decisions, and enterprises to carry out risk management. Of course, we must also be soberly aware that some irrational factors and emergencies in financial activities are still difficult to fully capture by economic mathematical models. However, with the continuous enhancement of data technology and computing power, the ability to formulate economic mathematics and simulate financial and economic operations will continue to improve, and the integration between economic mathematics and financial and economic practice has broad prospects. This will also promote the entire social and economic activities to be more quantitative, intelligent and controllable.

References

[1] Thomas Boylan & Paschal O'Gorman. Philosophy of Mathematics and Economics.Taylor and Francis,2018.

[2] Wang,Y. Application of Economic Mathematics in the Financial and Economic Field. Theoretical and Natural Science,2025, 106:32-39.

[3] Sanjay Tripathi. Application of Mathematics in Financial Management. Advances in mathematical finance & applications, 2019, 4(2): 1-14.

[4] Ouyang, Z.S. and Mo, T.C. Research on the Measurement and Evaluation of Internet Finance Risks. Journal of Hunan University of Science and Technology (Social Sciences Edition), 2016, 19(03):173-178.

[5] Guo, H.Q. The Application of Economic Mathematics in Financial and Economic Analysis. Market Weekly, 2024, 37(29):99-102.

[6] Zheng, Y.R. The Application of Economic Mathematics in Corporate Finance. Shanghai Enterprise, 2024, 2:57-59.

[7] Yu,S. Research on the Mathematical Application in Economics. Advances in Economics, Management and Political Sciences,2023, 16:194-199.

[8] Falahati K.Examining the application of mathematics in economics. Eurasian Journal of Economics and Finance ,2019. doi:10.15604/ejef.2019.07.02.003.