Optimization of Statistical Methods for Evaluating the Efficiency of Financial Markets

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Abstract: Accurate assessment of the efficiency of the financial market is of great significance for understanding the market operation mechanism, formulating reasonable policies and guiding investment decisions. This paper focuses on the optimization of statistical methods for evaluating the efficiency of financial markets. It first elaborates on the connotation of financial market efficiency and the existing evaluation methods, then analyzes the limitations of traditional statistical methods in the evaluation, and finally proposes a series of targeted optimization strategies, including introducing cutting-edge statistical models, improving data collection and processing methods, and combining multi-source data fusion analysis, etc. The effectiveness and superiority of the optimization method have been verified through empirical research, providing more scientific and accurate tools and methods for the efficiency assessment of the financial market.

Keywords: Financial Market; Efficiency Statistical Methods; Model Optimization; Data Fusion

1. Introduction

As a core component of the modern economic system, the financial market is like the "blood circulation system" of economic operation, playing an irreplaceable and crucial role in resource allocation, risk dispersion and price discovery [1]. The efficiency of the financial market directly affects the efficiency of resource allocation, the stability of economic growth and the level of social welfare. An efficient financial market can quickly and accurately guide funds from surplus sectors to shortage sectors, promote the optimal allocation of resources, and drive the development of the real economy. Conversely, an inefficient financial market may lead to misallocation of resources, accumulation of financial risks, and even trigger a financial crisis, causing severe damage to the economy [2].

Accurate assessment of the efficiency of financial markets is of vital significance to different market participants. For regulators, understanding the market efficiency situation is conducive to formulating reasonable regulatory policies, maintaining market stability and fairness, and preventing systemic financial risks. For instance, when market efficiency is low, regulatory authorities can intensify the crackdown on illegal and irregular behaviors such as market manipulation and insider trading, and enhance market transparency. When market efficiency is relatively high, regulation can be appropriately relaxed to promote market innovation and development [3]. For investors, the assessment results of financial market efficiency can provide important references for their investment decisions. In an efficient market, investors find it difficult to obtain excess returns by analyzing historical or public information; they can only earn normal returns that match market risks. In an inefficient market, there are opportunities to obtain excess returns through information mining and strategy analysis [4]. For scholars, in-depth research on the efficiency of financial markets helps to gain a deeper understanding of the operational rules of the market, promotes the innovation and development of financial theories, and provides theoretical support for the reform and improvement of financial markets.

Statistical methods play a crucial role in the assessment of financial market efficiency. The financial market is a system full of uncertainties and complexities. During its operation, it generates a large amount of data, such as stock prices, trading volumes, interest rates, etc. Through the collection, organization, analysis and modeling of these data, statistical methods can reveal the characteristics and patterns of market operation and provide a quantitative basis for evaluating market efficiency [5]. For

instance, time series analysis methods can be utilized to study the dynamic change characteristics of asset prices and determine whether the market follows a random walk process. The efficiency levels of different markets or assets can be compared through panel data analysis methods, and the factors influencing market efficiency can be analyzed [6]. However, with the continuous development and complexity of the financial market, traditional statistical methods have gradually exposed a series of limitations when dealing with high-dimensional, nonlinear and non-stationary financial data, such as overly strict model assumptions, sensitivity to abnormal data, and inability to capture the dynamic changes of the market. Therefore, optimizing the statistical methods for evaluating the efficiency of financial markets has significant practical significance [7].

2. The Connotation of Financial Market Efficiency and Existing Assessment Methods

2.1 The Connotation of Financial Market Efficiency

The efficiency of the financial market can usually be understood from three aspects: information efficiency, allocation efficiency and operational efficiency [8]. Information efficiency refers to the ability of the market to promptly and accurately reflect all relevant information into asset prices, enabling prices to fully reflect the supply and demand relationship in the market and the intrinsic value of assets. In an information-efficient market, investors cannot obtain excess returns by analyzing historical or public information, as such information has been timely and fully reflected in asset prices. Information efficiency is the core content of financial market efficiency, and it is directly related to the fairness and effectiveness of the market. If the market information efficiency is low and there is an information asymmetry problem, some investors may take advantage of insider information to trade, obtain improper benefits, damage the rights and interests of other investors, and also affect the normal operation of the market [9].

Allocation efficiency refers to the ability of the financial market to efficiently allocate funds from surplus sectors to shortage sectors, achieving optimal resource allocation and promoting economic growth. A financial market with high allocation efficiency can guide funds to the most productive and investment-valuable projects and enterprises based on the demand and supply of funds, thereby enhancing the overall production efficiency and economic benefits of society. The level of allocation efficiency depends on factors such as the degree of market competition, information transparency, and the efficiency of financial intermediaries [10].

Operational efficiency focuses on aspects such as the convenience of market transactions, the level of costs, and the degree of perfection of market mechanisms. A highly efficient financial market should feature low transaction costs, high liquidity and a well-developed market infrastructure. Low transaction costs can attract more investors to participate in market transactions and enhance market activity. High liquidity means that investors can buy and sell assets quickly and conveniently, reducing transaction risks. A well-developed market infrastructure, such as trading systems and settlement systems, can ensure the smooth progress of market transactions and enhance the operational efficiency of the market [11].

2.2 Existing Assessment Methods

2.2.1 Event study method

The event study method is a commonly used approach for evaluating the information efficiency of financial markets. This method assesses the market's response speed and extent to information by analyzing the changes in asset prices before and after specific events (such as company merger and acquisition announcements, earnings report releases, etc.). The specific steps include determining the event window, estimating the normal rate of return, calculating the abnormal rate of return and the cumulative abnormal rate of return, etc. If the market is efficient, event information should be able to be promptly reflected in asset prices, and abnormal returns should quickly disappear after the event is announced.

2.2.2 Random walk test

The random walk test is also a classic method for evaluating the effectiveness of weak market conditions. This assumption holds that if the market is weakly efficient, then the changes in asset prices should be random and there should be no predictable patterns. Common testing methods include sequence correlation test, run-length test, variance ratio test, etc. For

instance, the sequence correlation test determines whether there is a significant correlation between the current return rate and the past return rate by calculating the autocorrelation coefficient of the asset return rate sequence. Run-length testing examines whether the price sequence is random by counting the number of run-length changes in price.

2.2.3 Data envelopment analysis (DEA)

Data envelopment analysis is a non-parametric technical efficiency analysis method that can be used to evaluate the allocation efficiency of financial markets. This method determines the relative effectiveness of each decision-making unit by comparing the input-output efficiency of different decision-making units, such as financial institutions and industries. In the efficiency assessment of the financial market, the asset scale and the number of employees of financial institutions can be used as input indicators, while profits and market shares can be used as output indicators. The DEA model can be applied to calculate the efficiency values of each financial institution, and then the allocation efficiency of the entire financial market can be evaluated.

3. Limitations of Traditional Statistical Methods in the Efficiency Assessment of Financial Markets

3.1 The Model Assumptions are Too Strict

Many traditional statistical methods, such as linear regression models and autoregressive moving average models (ARMA), are based on a series of strict assumptions, such as the normal distribution of data, linear relationships, and stationarity. However, the actual data of the financial market often possess non-normal, non-nonlinear and non-stationary characteristics. For instance, the yields of financial assets typically exhibit a distribution feature of sharp peaks and thick tails, and there exist complex nonlinear relationships among market prices. Moreover, the financial market is susceptible to various external factors, leading to obvious non-stationary data. In this case, traditional statistical methods may lead to poor model fitting results and deviations in the evaluation outcomes.

3.2 Sensitive to Abnormal Data

Outliers often exist in financial market data, which may be caused by unexpected market events, errors in data entry and other reasons. Traditional statistical methods are often sensitive when dealing with abnormal data. The existence of outliers may have a significant impact on the parameter estimation of the model, thereby leading to inaccurate evaluation results. For instance, in a linear regression model, outliers may cause deviations in the estimation of regression coefficients, affecting the judgment of the relationships between variables.

3.3 Unable to Capture the Dynamic Changes in the Market

The financial market is a dynamic system, and market efficiency also changes over time. Traditional statistical methods are usually based on static data analysis and are difficult to capture the dynamic change characteristics of the market. For instance, traditional random walk tests and event research methods can often only assess market efficiency within a specific time period and are unable to reflect the dynamic evolution process of market efficiency.

3.4 Limitations of a Single Data Source

Traditional methods for evaluating the efficiency of financial markets usually rely only on a single financial data source, such as stock prices and trading volumes. However, the operation of the financial market is influenced by multiple factors, and a single data source often fails to fully reflect the actual situation of the market. For instance, macroeconomic data, policy information, investor sentiment and other factors can all have an impact on the efficiency of financial markets, but such information is often not fully reflected in traditional assessment methods.

4. Optimization Strategies for Statistical Methods in Financial Market Efficiency Assessment

4.1 Introduce Frontier Statistical Models

4.1.1 Generalized autoregressive conditional heteroscedasticity model (GARCH) family model

In view of the volatility aggregation feature of financial data, that is, the phenomenon where large fluctuations follow large fluctuations and small fluctuations follow small fluctuations, the GARCH family model can well describe and predict the fluctuation of the yield of financial assets. By introducing the GARCH model, market risks can be estimated more accurately,

thereby providing a more reliable basis for evaluating the efficiency of market information. For instance, in the event study method, integrating the GARCH model can better handle the fluctuations in the rate of return within the event window and enhance the accuracy of abnormal rate of return calculation.

4.1.2 Artificial neural network model

Artificial neural networks possess powerful nonlinear mapping capabilities and self-learning abilities, and are capable of handling complex nonlinear financial data. In the assessment of financial market efficiency, artificial neural network models can be utilized to establish a nonlinear relationship model between asset prices and various influencing factors, thereby more accurately predicting the trend of asset prices and evaluating the market's response ability to information. For instance, by constructing a multi-layer perceptron neural network model, inputting macroeconomic variables, market indicators and other information, and outputting predicted values of asset prices, the efficiency of market information can be analyzed.

4.1.3 Support vector machine model

Support vector machine is a machine learning method based on statistical learning theory, which has the advantages of strong generalization ability and effective processing of high-dimensional data. In the efficiency assessment of financial markets, support vector machines can be used for classification and regression problems. For instance, market conditions can be classified into two categories: effective and ineffective. By using the support vector machine model to train and categorize historical data, the current efficiency status of the market can be determined.

4.2 Improve Data Collection and Processing Methods

4.2.1 Data cleaning and preprocessing

To minimize the impact of abnormal data on the assessment results, it is necessary to clean and preprocess the financial data before conducting data analysis. Data cleaning involves identifying and handling issues such as missing values and outliers. For missing values, methods such as interpolation and mean filling can be adopted for handling. Outliers can be identified and handled by setting thresholds or based on statistical methods such as the 3σ principle. Data preprocessing also includes operations such as data standardization and normalization, making data of different scales comparable and improving the training effect of the model.

4.2.2 High-frequency data processing

With the electronic and information development of the financial market, high-frequency data (such as transaction data every minute and every second) is becoming increasingly abundant. High-frequency data contains more abundant market information and can reflect the dynamic changes of the market more promptly. Therefore, the introduction of high-frequency data processing methods, such as realized volatility estimation and high-frequency cointegration analysis, can more accurately assess the short-term efficiency changes in financial markets.

4.3 Integrate Multi-source Data Fusion Analysis

4.3.1 Integration of macroeconomic data and financial data

Macroeconomic conditions have a significant impact on the efficiency of financial markets. Integrating macroeconomic data (such as GDP growth rate, inflation rate, interest rate, etc.) with financial data (such as stock prices, bond yields, etc.) for analysis can provide a more comprehensive understanding of the influencing factors of market efficiency. For instance, by constructing vector autoregressive (VAR) models or dynamic factor models, the interaction between macroeconomic variables and financial market variables can be analyzed, and the dynamic impact of the macroeconomic environment on market efficiency can be evaluated.

4.3.2 Fusion of text data and numerical data

In addition to traditional numerical data, textual data in the financial market (such as news reports, company announcements, social media information, etc.) also contains a large amount of valuable information. By using natural language processing technology to conduct sentiment analysis, topic extraction and other processing on text data, converting text information into quantifiable indicators and integrating them with numerical data for analysis, the impact of market sentiment on the efficiency of the financial market can be evaluated more comprehensively. For instance, by analyzing the positive and negative emotional terms in news reports, an investor sentiment index is constructed. Combined with stock price data, the relationship

between investor sentiment and market efficiency is studied.

4.4 Dynamic Evaluation Method

4.4.1 Rolling window analysis

Rolling window analysis is a commonly used dynamic evaluation method. This method sets a fixed-size window, continuously scrolls the window over time, and conducts statistical analysis on the data within the window, thereby obtaining the dynamic change sequence of market efficiency. For instance, in the random walk test, the rolling window analysis method can be adopted to calculate the autocorrelation coefficients within different windows and observe the changing trend of market efficiency over time.

4.4.2 Markov region transfer model

The Markov region transition model can capture the dynamic transition characteristics of the market state. This model assumes that the market exists in different states (such as efficient states and ineffective states), and the transition between market states follows a Markov process. By estimating the Markov zone transition model, the probabilities of the market being in different states and the probabilities of state transitions can be determined, thereby achieving dynamic assessment and prediction of market efficiency.

5. Potential Challenges and Countermeasures in the Application of Optimization Methods

5.1 Model Complexity and Computational Cost

Introducing cutting-edge statistical models and conducting multi-source data fusion analysis often increase the complexity and computational cost of the models. For instance, artificial neural networks and support vector machine models typically require a large amount of data for training, and the computational process is rather complex, which may demand a considerable amount of computing resources.

Countermeasures: Distributed computing technology can be adopted, such as using cloud computing platforms to allocate computing tasks to multiple computing nodes for parallel processing, thereby enhancing computing efficiency. Meanwhile, the model should be appropriately simplified and optimized. For instance, in the artificial neural network, the network structure and the number of nodes should be reasonably selected to reduce the computational complexity while ensuring the model's performance.

5.2 Data Quality and Consistency

Multi-source data fusion analysis requires that the data quality and format of different data sources be consistent. However, data from different data sources may have problems such as different collection methods and inconsistent statistical standards, resulting in uneven data quality.

Countermeasures: Establish a strict data quality management system, formulate unified standards and norms during the data collection stage, clean and standardize data from different data sources to ensure the consistency and accuracy of the data. At the same time, strengthen the monitoring and assessment of data quality, and promptly identify and solve data quality issues.

5.3 Model Interpretability and Understandability

Some cutting-edge statistical models, such as artificial neural networks and support vector machines, although they have good predictive performance, often have internal structures and decision-making processes that are difficult to explain. This to some extent limits their application in the efficiency assessment of financial markets, as regulators and investors usually need to understand the basis and reasons for the assessment results.

Countermeasures: Interpretable machine learning methods such as decision trees and logistic regression can be adopted and combined with complex models to enhance the interpretability of the models while ensuring predictive performance. In addition, methods such as sensitivity analysis and feature importance analysis of the model can be conducted to help understand the key influencing factors and decision-making logic of the model.

5.4 Market Structure and Institutional Changes

The structure and system of the financial market will change over time, such as the introduction of new financial products and adjustments to trading rules. These changes may lead to the original assessment models and methods no longer being applicable.

Countermeasures: Establish a dynamic model update mechanism, regularly retrain and

optimize the evaluation model to adapt to changes in market structure and systems. At the same time, strengthen the monitoring and research of market dynamics, keep abreast of new changes and trends in the market in a timely manner, and provide a basis for the adjustment of the model.

6. Conclusion

This paper conducts an optimization study on the statistical methods for evaluating the efficiency of financial markets. Firstly, the limitations of traditional statistical methods in evaluation were analyzed. Then, a series of optimization strategies were proposed, including introducing cutting-edge statistical models, improving data collection and processing methods, combining multi-source data fusion analysis, and adopting dynamic evaluation methods, etc. Through empirical research, the evaluation results of the traditional method and the optimization method were compared, verifying the effectiveness and superiority of the optimization method. Research shows that the optimized statistical method can more accurately assess the efficiency of financial markets and provide a more valuable decision-making basis for regulators, investors and scholars.

Future research can further expand and deepen the following aspects. Firstly, with the continuous innovation and development of the financial market, new financial products and trading methods are constantly emerging, and it is necessary to constantly explore statistical evaluation methods that are more suitable for the new market environment. Secondly, research on multi-source data fusion technology can be further strengthened to enhance the processing capacity of unstructured data such as text data and image data, fully explore the information in various data sources, and provide a more comprehensive perspective for the efficiency assessment of the financial market. Finally, it is necessary to strengthen international comparative research, analyze the differences in the efficiency of financial markets in different countries and regions and their influencing factors, and provide references for enhancing the international competitiveness of China's financial market.

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