The Application of Quantitative Analysis in the Dynamic Adjustment of Fixed Income Bond Investment Portfolios in the Securities Field

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Abstract: This paper deeply explores the application of quantitative analysis in the dynamic adjustment of fixed-income bond investment portfolios in the securities field. By expounding the relevant theories of quantitative analysis and fixed-income bond investment portfolios, analyzing their mechanism of action, and evaluating the effects in combination with practical cases, it reveals the importance of quantitative analysis in this field. At the same time, it puts forward countermeasures for the challenges faced during the application process, aiming to provide theoretical and practical references for investors to use quantitative means to optimize their fixed-income bond investment portfolios.

keywords**:** quantitative analysis; fixed-income bonds; investment portfolio; dynamic adjustment

1. Introduction

In the securities market, fixed-income bond investment is an important investment method, and the construction and management of its investment portfolio are crucial for investors to achieve the goal of stable returns.[1] The traditional management of fixed-income bond investment mainly relies on empirical judgment. However, with the increasing complexity of the market and the continuous emergence of financial innovations, this method gradually fails to meet the needs of investors. Quantitative analysis technology, with its advantages such as systematicness, objectivity, and high efficiency, provides new ideas and methods for the dynamic adjustment of fixed-income bond investment portfolios.[2] Through quantitative analysis, it is possible to measure risks more accurately, predict returns, optimize asset allocation, and achieve the dynamic balance and maximum returns of the investment portfolio. [3]Therefore, studying the application of quantitative analysis in the dynamic adjustment of fixed-income bond investment portfolios has important theoretical and practical significance.[4]

2. Relevant Theories of Quantitative Analysis and Fixed-Income Bond Investment Portfolios

2.1 Overview of Quantitative Analysis

Quantitative analysis integrates knowledge from mathematics, statistics, and computer science into the financial domain. By creating mathematical models and algorithms, it analyzes and processes financial market data to facilitate scientific and accurate investment decisions. This process encompasses data collection, organization, modeling, backtesting, and strategy implementation.In securities investment, quantitative analysis is applicable to risk assessment, return prediction, and asset pricing. For instance, historical price data can be used to build time series models for predicting bond price trends, and statistical arbitrage models can capture market price discrepancies for profit.In the past decade, the asset management scale of quantitative investment strategies has seen consistent growth. By 2024, it had surged from approximately $1 trillion in 2010 to over $8 trillion, reflecting a compound annual growth rate of around 20%. This growth underscores the extensive use and significance of quantitative analysis within the financial market.

During the quantitative analysis process, the scope of data collection is extremely wide, covering macroeconomic data such as the growth rate of gross domestic product (GDP) and the consumer price index (CPI), as well as micro-level data such as corporate financial statements and high-frequency price data of bond transactions. In the modeling link, in addition to common linear regression models, complex neural network models, support vector machine models, etc. will also be used to better mine the potential laws in the data. In the model backtesting stage, the performance of investment strategies under different market environments will be simulated, and the model parameters will be continuously optimized through multiple rounds of backtesting results to ensure the effectiveness of the strategy in practical applications.

2.2 Basics of Fixed-Income Bond Investment Portfolios

Fixed-income bonds refer to bonds in which the issuer promises to pay interest to investors at an agreed interest rate within a certain period and repay the principal when the bond matures. Its characteristics include relatively stable returns and low risks. Common types include treasury bonds, corporate bonds, and financial bonds. The goal of constructing a fixed-income bond investment portfolio is to maximize investment returns while meeting the risk tolerance of investors. When constructing an investment portfolio, factors such as the credit risk, interest rate risk, duration, and convexity of bonds need to be considered. For example, bonds with different credit ratings have significant differences in yields and default risks. Bonds with high credit ratings have relatively low yields but small default risks, while bonds with low credit ratings are the opposite.

Table 1. The average yields and default rates of corporate bonds with different credit ratings

Credit Rating	Average Yield (%)	Default Rate (%)
AAA	3.5	0.1
AA+	4.0	0.3
AA	4.5	0.5
A+	5.0	1.0
A	5.5	1.5

Taking treasury bonds as an example, due to their endorsement by national credit, the credit risk is extremely low. When the market fluctuates greatly, treasury bonds are often regarded as safe-haven assets, and a large amount of funds will flow into the treasury bond market, driving up the price of treasury bonds and reducing the yield. The credit rating of corporate bonds is directly related to the financial situation of the issuing enterprise. Bonds issued by enterprises with good financial conditions and strong profitability often receive high credit ratings. For example, the AAA-rated corporate bonds issued by a large state-owned enterprise have a very low possibility of default due to their stable cash flow and strong asset base. However, their coupon rates are only slightly higher than those of treasury bonds with the same maturity to compensate investors for the slight credit risk premium they bear.

2.3 Necessity and Influencing Factors of Dynamic Adjustment

Fixed-income bond investment portfolios need to be dynamically adjusted mainly for the following reasons. On the one hand, the market environment is constantly changing, and factors such as interest rate fluctuations, changes in the economic situation, and credit events will affect bond prices and the risk-return characteristics of the investment portfolio. For example, when market interest rates rise, bond prices usually fall, leading to a shrinkage in the market value of the investment portfolio. On the other hand, investors' own risk preferences, investment objectives, etc. may also change. There are many factors that affect the dynamic adjustment of the investment portfolio, such as macroeconomic indicators such as GDP growth rate and inflation rate, monetary policies such as central bank interest rate adjustments and open market operations, and changes in the financial situation of bond issuers, all of which will prompt investors to adjust the investment portfolio. Taking 2018 as an example, affected by the slowdown in macroeconomic growth and monetary policy adjustments, the yield of 10-year treasury bonds decreased from 3.9% at the beginning of the year to 3.2% at the end of the year. During this period, many fixed-income bond investment portfolios adjusted their asset allocations in response to interest rate changes.

When the GDP growth rate slows down, the market's expectations for the economic outlook weaken, and corporate profits may be affected, which will increase the default risk of corporate bonds. At this time, investors may reduce their holdings of corporate bonds and increase the proportion of relatively safe bonds such as treasury bonds. The rise in the inflation rate will erode the real yield of bonds. If the inflation expectation strengthens, investors may choose to allocate bond varieties linked to inflation to ensure the real purchasing power of investment returns. In terms of monetary policy, when the central bank lowers interest rates, the relative attractiveness of already issued bonds increases, and their prices rise. Investors can appropriately increase their bond holdings. When the central bank withdraws funds through open market operations and market liquidity tightens, bond prices may fall, and investors need to consider reducing their bond holdings.

3. The Mechanism of Action of Quantitative Analysis in the Dynamic Adjustment of Fixed-Income Bond Investment Portfolios

3.1 Risk Measurement and Assessment

Quantitative analysis measures and assesses the risks of fixed-income bond investment portfolios through a variety of models. Commonly used risk measurement indicators include VaR (Value at Risk), CVaR (Conditional Value at Risk), etc. VaR can measure the maximum loss that an investment portfolio may suffer in a specific period in the future under a certain confidence level. For example, if the VaR value of a fixed-income bond investment portfolio is 5 million yuan within 10 days at a 95% confidence level, it means that there is a 95% probability that the loss of this investment portfolio will not exceed 5 million yuan within the next 10 days. In addition, quantitative models can also decompose and evaluate interest rate risk, credit risk, liquidity risk, etc. By analyzing the impact of different risk factors on the value of the investment portfolio, investors can have a clearer understanding of the risk situation faced by the investment portfolio, providing a basis for dynamic adjustment.

In actual operation, methods such as the historical simulation method, parametric method, and Monte Carlo simulation method can be used to calculate the VaR value. The historical simulation method estimates the VaR by reviewing historical data and simulating the performance of the investment portfolio under past market fluctuations. The parametric method assumes that the investment portfolio returns follow a specific distribution (such as the normal distribution) and calculates the VaR using the distribution parameters. The Monte Carlo simulation method calculates the value changes of the investment portfolio under different scenarios by randomly simulating a large number of market scenarios, and then obtains the VaR value. For the assessment of interest rate risk, the duration model can measure the sensitivity of bond prices to interest rate changes. The longer the duration, the greater the interest rate risk. In terms of credit risk assessment, quantitative models will analyze the financial ratios of bond issuers, such as the debt-to-asset ratio and current ratio, and combine with credit rating data to build a credit risk scoring system to predict the default probability of bonds.

3.2 Return Prediction and Optimization

Quantitative analysis uses historical data and economic models to predict the returns of fixed-income bonds. For example, by constructing a multi-factor model and considering the impacts of interest rate factors, credit factors, liquidity factors, etc. on bond yields, it predicts the yield performance of different bonds in a certain period in the future. Based on the return prediction, optimization algorithms are used to optimize the investment portfolio. Common optimization objectives include maximizing the expected return of the investment portfolio and maximizing the return under certain risk constraints. Suppose the initial allocation of an investment portfolio is 60% in treasury bonds and 40% in corporate bonds. After quantitative optimization, it is adjusted to 50% in treasury bonds, 30% in corporate bonds, and 20% in financial bonds. The expected annualized return is increased from 4% to 4.5% at the same risk level, achieving return optimization.

When constructing a multi-factor model, statistical methods such as principal component analysis (PCA) will be used to screen and reduce the dimensions of numerous influencing factors, remove highly correlated factors, and retain the key factors that have a significant impact on bond yields. In the process of optimizing the investment portfolio, commonly used algorithms include the quadratic programming algorithm and the genetic algorithm. The quadratic programming algorithm solves the quadratic objective function under risk constraints to obtain the optimal asset allocation weights. The genetic algorithm simulates the biological evolution process, and through operations such as population selection, crossover, and mutation, it gradually searches for the optimal allocation scheme of the investment portfolio, which has good adaptability in a complex investment environment.

3.3 Adjustment of Asset Allocation Proportions

Based on the results of risk measurement and return prediction, quantitative analysis provides guidance for the adjustment of asset allocation proportions in fixed-income bond investment portfolios. When the quantitative model shows that the risk of a certain type of bond increases or the expected return decreases, investors can reduce the proportion of this type of bond in the investment portfolio and increase the allocation of other more promising bonds. For example, when quantitative analysis predicts that market interest rates will rise and bond prices will fall, investors can reduce the holding proportion of bonds with a longer duration and increase the allocation of short-term bonds or cash equivalents to reduce the interest rate risk of the investment portfolio.

Table 2. The situation of an investment portfolio's asset allocation proportion before and after adjustment under the guidance of quantitative analysis

Asset Category	Proportion Before Adjustment	Proportion After Adjustment
Treasury Bonds	50	40
Corporate Bonds	30	25
Financial Bonds	10	15
Cash and Equivalents	10	20

If the quantitative model predicts that the credit risk of a certain industry will increase due to intensified industry competition, the holding proportion of corporate bonds in this industry in the investment portfolio should be reduced accordingly. At the same time, if market liquidity tightens, short-term bonds have strong liquidity and are less affected by liquidity risk, so their allocation proportion can be appropriately increased. When adjusting the asset allocation proportion, the factor of transaction costs also needs to be considered. Frequent and large-scale adjustments may lead to high transaction costs, offsetting part of the investment returns. Therefore, quantitative analysis will also comprehensively weigh the adjustment returns and costs to determine a reasonable adjustment range and frequency.

4. Case Analysis of the Application of Quantitative Analysis in the Dynamic Adjustment of Fixed-Income Bond Investment Portfolios

4.1 Case Selection and Data Source

This analysis case studies a fixed - income bond investment fund under a large asset management company, established in 2015 and investing in treasury, corporate, and financial bonds. Data from 2015 - 2024, including fund quarterly reports, market bond transactions, and macroeconomic data, were collected. Key findings: the fund's treasury bond holding proportion decreased slightly to 28% in 2024; corporate bond yields correlated with credit ratings and the yield spread with treasuries narrowed as market rates fell; market interest rate fluctuations, affected by monetary policies, impacted bond prices and portfolio value, with milder effects in 2024.

When collecting the quarterly report data of the fund, the specific holding quantities, market values, and the proportions of various bonds in the total assets of the investment portfolio at the end of each quarter are recorded in detail. For the publicly available bond transaction data in the market, a professional financial data platform is used to obtain information such as the daily transaction prices and volumes of bonds, and the data are summarized and statistically analyzed on a quarterly basis. The macroeconomic data come from official channels such as the National Bureau of Statistics and the central bank, including quarterly GDP growth rates, inflation rates, central bank benchmark interest rates, etc., to comprehensively reflect the changes in the market macroeconomic environment.

4.2 Construction and Application of the Quantitative Model

A quantitative analysis system based on a multi - factor model has been built, using the 10 - year treasury bond yield, corporate bond credit spread, and bond market trading volume as independent variables to predict bond yields.In 2024, the 10 - year treasury bond yield dropped from 2.56% to 1.68% due to expansionary policies and risk - aversion. Corporate bond credit spreads diverged: AAA, AA +, and AA spreads for 3 - year bonds rose slightly, while the AA - spread dropped sharply, reflecting a more selective market. Meanwhile, bond market trading volume increased, with treasury bonds hitting a 400% turnover rate.The model predicted wider corporate bond credit spreads and downward yield pressure in Q1 2024, prompting adjustments to corporate bond holdings to optimize the portfolio's risk - return balance.

In the process of constructing the multi-factor model, the stationarity test is first carried out on the selected factors to ensure that the data meet the requirements of regression analysis. For the interest rate factor, not only the absolute level of the yield of 10-year treasury bonds is considered, but also the impact of its short-term fluctuation trend on the bond yield is analyzed. In terms of the credit factor, the changing laws of the credit spreads of corporate bonds in different industries are deeply studied, as well as the correlation between the credit spreads and the macroeconomic cycle. For the liquidity factor, through the time series analysis of the trading volume of the bond market, the transmission mechanism of the overall market liquidity situation on the bond yield is investigated. When applying the model, the factor data are updated in real time, and the latest market information is used to predict bond returns and evaluate risks, providing timely and accurate bases for investment decisions.

5. Challenges and Countermeasures Faced during the Application Process

5.1 Data Quality and Model Effectiveness Issues

In the process of quantitative analysis, data quality is of utmost importance. Inaccurate, incomplete, or biased data can lead to distorted model results. For example, abnormal price fluctuations in bond transaction data may affect the accuracy of yield calculations. Countermeasures include establishing a strict data cleaning process, conducting multiple verifications of the original data, and removing outliers.

At the same time, data source channels should be broadened, and data from multiple data providers should be integrated to improve data reliability. Regarding the issue of model effectiveness, the model needs to be backtested and verified regularly, and model parameters and structures should be adjusted in a timely manner according to market changes to ensure that the model can accurately reflect market laws.

The data cleaning process can utilize data mining techniques, such as cluster analysis to detect outliers in the data, and correct or eliminate abnormal price data. In terms of expanding data sources, in addition to commonly used financial data service providers, official data from exchanges, data from industry research institutions, etc. can also be referred to. For model backtesting, it should be carried out not only in historical normal market environments but also by simulating extreme market scenarios, such as the market conditions during the financial crisis, to test the robustness of the model. When new trading rules, regulatory policy changes, and other situations occur in the market, these factors' impacts on the model should be analyzed in a timely manner, and the model structure should be adjusted, such as adding new policy variable factors, to ensure the continuous effectiveness of the model.

5.2 Challenges of Market Environment Changes and Model Adaptability

The financial market environment is complex and changeable, and quantitative models may not be able to adapt to new market situations in a timely manner. For example, sudden macroeconomic events or policy adjustments may lead to changes in the operating laws of the bond market. To address this challenge, investors should establish a mechanism for real-time market monitoring to capture market change signals promptly. At the same time, a combination of multiple models should be adopted, such as introducing machine learning models on the basis of traditional multi-factor models, to improve the model's adaptability to complex market environments. In addition, the model should be stress-tested regularly to evaluate its performance under extreme market conditions and formulate contingency plans in advance.

Real-time market monitoring can utilize big data analysis technology to capture and analyze information such as news, social media sentiment, and macroeconomic data releases in real time, and quickly perceive changes in market sentiment and macroeconomic trends. When combining multiple models, the traditional multi-factor model can give full play to its advantage of summarizing historical laws, while the machine learning model can use its powerful self-learning ability to mine new relationships and patterns from a vast amount of market data. In the stress test, different degrees of market shock scenarios, such as large fluctuations in interest rates and a sharp expansion of credit spreads, should be set to evaluate the risk exposure and return changes of the investment portfolio under these scenarios, and adjust the investment portfolio strategy and model parameters according to the test results.

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