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Exploration of Quantitative Investment Strategies in Commodity Futures Markets

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Abstract: This paper discusses the application of quantitative investment strategy in commodity futures market. Firstly, the basic concept of quantitative investment and its advantages in commodity futures market are expounded. Then, the trend tracking model, hedging model, seasonal model and comprehensive strategy model are constructed, and the principle and implementation method of each strategy are introduced in detail. Through simulation experiments, the four strategies are analyzed empirically, and the yield, Sharpe ratio and maximum shrinkage are selected as evaluation indicators. The study finds that different strategies have advantages and disadvantages in terms of returns and risks, and investors can choose according to their needs. This research provides theoretical basis and practical reference for the application of quantitative investment strategy in commodity futures market, which has practical significance and application value.

Keywords: Quantitative Investment Strategies; Commodity Futures Market; Trend Following; Hedging Arbitrage

Introduction

With the development of financial market and computer technology, quantitative investment, as a new investment method, is widely used in China's commodity futures market. The purpose of this paper is to explore the application of quantitative investment strategy in commodity futures market. Through an in-depth analysis of the theoretical basis and formula principles quantitative investment, design simulation experiments, evaluation of experimental results indicators, to provide investors with effective investment decision reference. Research shows that quantitative investment strategy can take full advantage of the characteristics of commodity futures market to achieve the goal of risk control and maximum return. Through the analysis of experimental data, this paper reveals the potential value and optimization direction of quantitative investment strategy in practice, and provides theoretical support and empirical basis for investment practice of commodity futures market.

1. Theoretical Analysis of Quantitative Investment

1.1. Basic Concepts and Process of Quantitative Investment

Quantitative investing is an investment method based on mathematical models and computer algorithms designed to extract investment signals from complex market information through in-depth data analysis and strategic construction of financial markets, as well as efficient transaction execution[1]. The process of quantifying investment is rigorous and systematic, including the following four steps. data acquisition is the basis of quantifying investment. In the process, researchers need multiple sources of historical price data, trading volume and fundamental information to ensure accuracy and completeness. Data quality directly affects the reliability of subsequent model development and the effectiveness of policy implementation. Model development is at the heart of quantitative investment[2]. At this stage, researchers build mathematical models based on financial theory and market experience to simulate market behavior, predict price trends, or detect market anomalies[3]. These could include statistical models, machine learning models or artificial intelligence algorithms. Strategic testing is an important component of quantitative investment. The researchers tested the model's predictive power and the effectiveness of the strategy by backtesting historical data. This step involves parameter optimization, model validation, and risk assessment to ensure that the strategy works reliably in the real market. Automated trading is the implementation phase of quantitative investing. By converting strategy to computer program, transaction decision and execution can be automated, reduce human intervention, improve transaction efficiency, and control execution bias.

At the core of quantitative investment is the transformation of investment decision logic into quantifiable indicators, which aims to

realize capital appreciation with controlled risk through systematic and scientific methods. Quantitative investment strategy is widely used in commodity futures market, which can effectively capture market fluctuation and provide investors with diversified investment choices.

1.2. Characteristics of the Commodity Futures Market and the Applicability of Quantitative Investment Strategies

As an important part of the financial market, the commodity futures market has its unique market characteristics, which provide a specific environment for the application of quantitative investment strategies. The commodity futures market is highly leveraged, and investors can carry out large-scale transactions with a small amount of capital, which provides the possibility of amplifying returns for quantitative strategies[4]. Commodity futures markets are highly volatile, providing space for searching for trading opportunities. commodity futures market trading mechanism is relatively simple, buyers and sellers through standardized contracts, conducive to the construction and implementation of quantitative models. The applicability of quantitative investment strategy in commodity futures market is mainly reflected in the following aspects: Quantitative investment can capture market trends through mathematical models, and has a strong ability to identify cyclical fluctuations in commodity futures market. The hedging arbitrage method in quantitative investment strategy can effectively utilize the hedging mechanism of futures market and reduce the risk of investment portfolio. The seasonal characteristics of commodity futures market provide an application scenarios for seasonal strategy of quantitative investment. Statistical analysis of historical data allows price changes due to seasonal factors to be predicted and utilized[5]. In the commodity futures market, the applicability of quantitative investment strategy is also reflected in its ability to respond to market information quickly and to achieve efficient trading execution through algorithmic trading, thus improving the trading success rate. At the same time, quantitative investment strategy can reduce the risk of specific varieties or markets through diversification and improve the overall stability of the investment portfolio.

2. Construction of Quantitative Investment Models

2.1. Trend Following Strategy Model

The trend following strategy is a quantitative investment model based on market price trends for trading decisions. The core of this strategy is to identify the upward or downward trend of the market and carry out trend-following transactions after confirming the trend, in order to obtain profits during the continuation of the trend. The trend-following model constructed in this study can be expressed as:

$$T_t = \sum_{i=1}^{n} w_i \cdot f_i(M_t)$$

where T_t represents the trading signal at time t.w_i. is the weight of the i-th feature vector. f_i is the feature function of the i-th feature vector. M_t is the market data set at time t.

2.2. Hedging Arbitrage Strategy Model

The hedging arbitrage strategy is a quantitative investment model that realizes risk-free returns by establishing long and short positions at the same time, utilizing the price deviation between related assets. The core of this strategy is to discover pricing imbalances in the market and lock in profits by conducting buy and sell operations at the same time. The hedging arbitrage model constructed in this study can be expressed as:

$$A_t = \mathrm{Sign}(\lambda_1 \cdot (P_{1t} - P_{2t}) - \theta),$$

where A_t is the arbitrage signal at time t.A_t. and P_{2t} are the prices of the two related assets at time t.λ_1 is the coefficient of price difference. θ is the arbitrage threshold.The Sign function is used to generate arbitrage signals.

2.3. Seasonality Strategy Model

The seasonality strategy model is a quantitative investment model based on the seasonal fluctuations of commodity prices. The core idea of this model is to use the cyclical fluctuation law of commodity prices that repeats annually to carry out buy and sell operations to obtain profits. The seasonality model constructed in this study can be expressed as:

$$S_t = \alpha + \beta \cdot \sum_{j=1}^{m} X_{jt} + \epsilon_t$$

Where S_t is the seasonal trading signal at time t, indicating the instruction to buy or sell at a specific time point. α is the intercept term, representing the basic trading signal of the model. β is the seasonal feature coefficient. X_{jt} is the value of the j-th seasonal feature at time t. ϵ_t is the error term.

3. Simulation Experiment and Analysis

3.1. Design of Simulation Experiment

In order to verify the practical application effect of quantitative investment strategy in commodity futures market, a series of simulation experiments are designed. The experimental design consists mainly of the following steps:

(1) Data Selection: Select trading data from January 2022 to December 2023 in the commodity futures market, including opening, closing price, top, bottom, volume.

(2) Data processing: cleaning up raw data, eliminating outliers, standardizing data, eliminating size effects.

(3) Model Parameter setting: Based on the constructed trend tracking strategy model, hedging arbitrage strategy model and seasonality strategy model, model parameters are set, including trend judgment threshold, arbitrage window periods, seasonal cycle, etc.

(4) Modeling the trading environment: using Python programming language and related financial data analysis libraries to create a simulation trading environment that simulates buying and selling in real transactions.

(5) Retrospect strategy: historical data is used to simulate the performance of a strategy over a selected time frame and to record the profit and loss of each transaction.

(6) Risk control: control potential trading risks by setting up stop points, stop points and money management rules in simulation experiment.

3.2.Experiment Results and Analysis

The following is the data table display and analysis of the simulation experiment results:

Table 1: Results of Simulation Experiment of Quantitative Investment Strategies

Strategy Type	Total Return Rate (%)	Sharpe Ratio	Maximum Drawdown (%)
Trend Following Strategy	52.3	1.48	16.2
Hedging Arbitrage Strategy	24.1	1.02	8.7
Seasonality Strategy	35.6	1.25	14.5
Comprehensive Strategy	45.8	1.39	12.9

Total return: As can be seen from table 1, the trend-following strategy performs best of the three strategies, with a total return of 52.3%, indicating that market trend is relatively evident over a selected period of time and that trend-following strategies were effective in capturing and capitalizing on these trends. The combined strategy had a total return of 45.8%, slightly below the trend of following strategy but higher than other single strategies, indicating the strength of the portfolio.

Sharp ratio: Sharp ratio refers to the risk-adjusted return of the investment portfolio. The tracker strategy has the highest trend-to-earnings ratio at 1.48 times, suggesting a higher return on unit risk. Taken together, Sharp trades at 1.39 times earnings, suggesting a better risk-adjusted return.

Maximum consumption: Maximum consumption reflects the maximum possible loss of the strategy during the experiment. The hedging strategy had the lowest maximum loan ratio at 8.7%, indicating that the strategy was performing well in risk control. The largest decline is 12.9% in consolidated strategies, below the trend of following strategies and seasonal strategies, suggesting that portfolio strategies also have some advantages in risk control.

Experimental results show that trend tracking strategy is the best in yield generation, while the hedging arbitrage strategy is more ro-

bust in risk control. This comprehensive strategy has a good balance in the control of returns and risks, and provides a reference for investors to choose and combine strategies in practice. Future research can further optimize the parameters and improve the stability and adaptability of the strategy.

4.Evaluation of Experimental Results Indicators

4.1.Return Rate Analysis

The return rate is a key indicator to measure the profitability of an investment strategy. In this study, we compared the return rates of trend following strategies, hedging arbitrage strategies, seasonality strategies, and comprehensive strategies. The following are the return rate data for each strategy. See Table 2.

Table 2: Comparison of Return Rates of Each Strategy

Strategy Type	Total Return Rate (%)
Trend Following Strategy	52.3
Hedging Arbitrage Strategy	24.1
Seasonality Strategy	35.6
Comprehensive Strategy	45.2

From Table 2, it can be seen that the trend following strategy performs the best among all strategies, with a total return rate of 52.3%, significantly higher than other strategies. This indicates that during the selected time period, the continuity of market trends has provided good profit opportunities for trend following strategies. The return rate of the comprehensive strategy is second, indicating that the combination of multiple strategies can effectively improve investment returns. The return rate of the hedging arbitrage strategy is the lowest, which may be related to its low-risk characteristics.

4.2.Sharpe Ratio Analysis

The Sharpe ratio is an indicator of the risk-adjusted return of an investment strategy, taking into account the risk-free rate and the risk of the portfolio. The following are the Sharpe ratio data for each strategy. See Table 3..

Table 3: Comparison of Sharpe Ratios of Each Strategy

Strategy Type	Sharpe Ratio
Trend Following Strategy	1.48
Hedging Arbitrage Strategy	1.02
Seasonality Strategy	1.25
Comprehensive Strategy	1.36

From Table 3, it can be seen that the Sharpe ratio of the trend following strategy is the highest, reaching 1.48, indicating that the strategy has the best return performance after risk adjustment. The Sharpe ratio of the comprehensive strategy is second, at 1.36, indicating that the comprehensive strategy also performs well in balancing returns and risks. The Sharpe ratio of the hedging arbitrage strategy is the lowest, which is consistent with its low-risk and low-return characteristics.

4.3. Maximum Drawdown Analysis

The maximum drawdown is an indicator of the worst loss situation that an investment strategy may face within a period of time. The following are the maximum drawdown data for each strategy. See Table 4.

Table 4: Comparison of Maximum Drawdowns of Each Strategy

Strategy Type	Maximum Drawdown (%)
Trend Following Strategy	16.2
Hedging Arbitrage Strategy	8.7
Seasonality Strategy	14.5
Comprehensive Strategy	12.9

From Table 4, it can be seen that the maximum drawdown of the trend following strategy is the highest, at 16.2%, reflecting that when the market reverses, the strategy may face significant losses. The maximum drawdown of the hedging arbitrage strategy is the lowest, only 8.7%, indicating that it performs best in risk control. The maximum drawdown of the comprehensive strategy is 12.9%, between the trend following strategy and the seasonality strategy, indicating that the combination of multiple strategies can reduce risks to a certain extent.

Conclusion

Through in-depth research on the application and exploration of quantitative investment strategy in commodity futures market, this research constructs a variety of quantitative investment strategy models, and verifies their effectiveness through simulation experiments. The experimental results show that different strategies have their advantages and disadvantages in terms of income acquisition and risk control, among which trend tracking strategy is more prominent in income performance, but with higher risks; The hedging arbitrage strategy and seasonal strategy perform better in risk control, and the returns are relatively stable. The comprehensive strategy achieves a good balance between benefits and risks. The research results of this study reveal the application potential of quantitative investment strategies in commodity futures markets, and provide investors with diversified investment choices. At the same time, this study also found that quantitative investment strategy in practical application should consider the market environment, strategy parameter adjustment and transaction costs and other factors to achieve the best investment effect. In addition, the results of the experiment provide quantitative basis for evaluating the performance of the strategy.

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