Study on Quantitative Investment Strategy of Commodity Futures Based on Market Money Flow Factor: Chinese Gold Futures Case

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Abstract. This paper constructs a quantitative trading strategy based on the fund flow model, and tests it on SHFE gold and COMEX gold futures respectively. The cumulative return rate in 2022-2023 is 45.3% and 51.2%, indicating that the quantitative trading strategy based on the fund flow model has certain universality and can be applied to other futures trading. And even transactions in other financial assets.

Keywords: Gold future, Quantitative trading, China

1 Introduction

Based on the quantitative trading strategy of commodity futures based on the analysis of capital flow in futures market, this paper describes the law of money flow in futures market by analyzing the historical data of commodity futures and combining the relevant background of futures market, and builds a strategy model. This paper calculates the correlation coefficient between the capital flow of gold futures contracts of Shanghai Futures Exchange and COMEX Exchange and commodity futures prices at different time frequencies, and establishes a linear regression model to study the impact of capital flow on gold commodity futures prices from 2014 to 2024. Secondly, this paper conducts ADF test on the data of capital flow direction and calculates its autocorrelation coefficient, and finds that the capital flow direction of each sector has a positive correlation persistence within 10 lag periods. Finally, this paper designs quantitative trading strategies based on the above findings.The backtest report shows that the cumulative yield of SHFE gold futures and COMEX gold futures is 45.3% and 51.2%, respectively, and the Sharpe ratio is 1.45 and 1.52.

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2 Related Literature

The research on the relationship between capital flow and commodity futures price is an interdisciplinary field, involving financial market, macroeconomics, investment behavior and commodity market. 1. Capital flow and price dynamics. It is generally believed that capital flow has a significant impact on commodity futures prices. For example, large inflows into commodity markets usually lead to higher prices, while outflows can lead to lower prices. This relationship may vary across commodities and market conditions (Ernst & Young, 2011[1]; Irwin & Zulauf, 2012[2]; Syed & Teo, 2004[10]); 2. The role of macroeconomic factors. Macroeconomic factors, such as interest rates, exchange rates and economic growth, also affect capital flows and commodity futures prices. For example, a low interest rate environment may prompt investors to seek higher returns in commodity futures markets, thus affecting prices (Mishra & Narayan, 2013[3]); 3. Investor behavior. Investor expectations and behavior have a significant impact on capital flows and price fluctuations. Optimistic market sentiment may attract more capital inflows, while pessimistic sentiment may lead to outflows (Kumar & Persaud, 2001[4]; Tang & Xiong,2012[11]); 4. Market structure and liquidity. Market structure and liquidity also have an impact on the relationship between capital flows and prices. A highly liquid market may reduce the short-term impact of capital flows on prices, while changes in market structure, such as changes in exchange rules, may also alter the pattern of capital flows (Harris et al., 2002[5]; Wang & Luo,2015[12]). 5. Speculation. Speculative capital flow plays an important role in commodity futures market. The participation of speculators can amplify price movements, especially when there is an imbalance between supply and demand in the market (Trolle & Xie, 2011[6]; Gorton & Rouwenhors,2006[8]). 6. Supply and demand. The fundamental supply and demand relationship of commodities is the key factor affecting futures prices. Money flows may affect prices in the short term, but long-term price trends are still dominated by supply and demand fundamentals (Dungey & Martin, 2015[7]; Masterman,2007[9]).

The existing research verifies the theoretical hypothesis through empirical analysis and provides some quantitative evidence of the impact of capital flow on commodity futures prices. However, some data on commodity futures markets may be difficult to access, or there are time span and frequency limitations, which may affect the accuracy and reliability of the research results. In particular, there are few researches on typical commodity futures in Chinese commodity futures market and American commodity futures market. With the increasing role of emerging markets in global commodity futures trading, it is important to study the capital flows and price relationships in these markets.

3 Dynamic Weighted Money Flow Mode

3.1 Money Flow Model Based on Futures Market

First of all, according to the definition of fund flow and the application of fund flow index in the stock market and stock index futures market, we do not completely overturn the influence of price fluctuation on fund flow when we establish the fund flow formula of commodity futures market. Combined with the existing research and the law of capital flow in commodity futures market, we believe that the impact of price changes on capital flow in commodity futures market cannot be ignored. There may be such a correlation that the rising price causes the inflow of funds in commodity futures, while the falling price causes the outflow of funds in commodity futures. Secondly, because there is a short-selling mechanism in the futures market, it is impossible to describe the real law of capital flow of the futures contract by directly using the fund flow formula in the stock market. For example, a decline in the price of a futures underlying contract may be caused by capital inflows or outflows.

According to the definition of the fund flow index of Dungey & Martin (2015)[7], combined with the real fund flow law of the underlying futures contract, we continue to introduce the open position factor into the original fund flow formula, and use the following formula to represent the fund flow of commodity futures products:

$$MoneyFlow = \int_{i}^{n} (Volume_i) * P_i * sgn(\alpha_i * \frac{P_i - P_{i-1}}{|P_i - P_{i-1}|} + \beta_i * \frac{I_i - I_{i-1}}{|I_i - I_{i-1}|})$$

In the futures market, because of the short-selling mechanism, the price of a futures underlying contract falls, which may be caused by capital inflows or outflows. The commonly used fund flow index formula in the stock market cannot describe the real fund flow law of futures contracts. Therefore, we further consider the open position factor, and the fund flow model constructed can be used to explain the short mechanism of the futures market. The calculation of weights is defined as the following formula:

$$\alpha_i = \frac{|P_i - P_{i-1}| + \varepsilon}{|P_i - P_{i-1}| + |I_i - I_{i-1}| + 2\varepsilon}$$

$$\beta_i = \frac{|I_i - I_{i-1}| + \varepsilon}{|P_i - P_{i-1}| + |I_i - I_{i-1}| + 2\varepsilon}$$

By giving weight to the change of futures price direction and the change of open position direction, we can measure the influence of the change of futures price and open position on the fund flow. P_i is the transaction price at moment i; P_{i-1} is the transaction price at moment i−1 before moment i; I_i is the open position at moment i; I_{i-1} is the open position at moment i-1; $Volume_i$ is the trading volume at moment i; α_i is the weight value of the change in the transaction price at moment i,which is specified by transaction facility; β_i is the weight value of the change in the open position at moment i, ε is an infinite small quantity greater than zero, and sgn(x) is a symbolic function.

$$sgn(x) = \begin{pmatrix} -1, x < 0 \\ 0, x = 0 \\ 1, x > 0 \end{pmatrix}$$

3.2 Design of Logistics Regression Strategy Based on Money Flow

In this paper, the closing time is set in the program, and the closing time is stipulated before 9:30 AM and after 14:50 PM, and no trading is carried out. In order to control risks, this paper sets a strict stop-loss and stop-gain mechanism for trading. openprice and histExtre variables are added to the model to record the opening price and the extreme value during the trading period to track stop-win and stop-loss. In the model, the stop-loss rate is 0.05, the stop-profit rate is 0.1, and the tracking stop-profit rate is 0.03. In addition, this paper selects the futures minute data from 20220101 to 20231231 for backtesting, the sampling frequency is 30 minutes, the training set sample number of the trading model is 2000, and the number of trading lots is 1000.

In order to further predict the rise and fall of futures prices in the future, we set up a binary Logistic regression model and introduced money flow, open position, trading volume, closing price and other indicators to predict the rise and fall of commodity futures prices in the next period. We construct the following binary Logistic model:

$$Logit(y) = ln(\frac{p_j}{1-p_j}) = b_0 + b_1 * MoneyFlow_{t,j} + b_2 * I_{t,5,j} + b_3 * \text{Volume}_{t,20,j} + b_4 * I_{t,20,j}$$

Where p_j refers to the probability of commodity futures price rising in the next phase of j futures contract; $1 - p_j$ indicates the probability of y = 0 (futures price falling); $MoneyFlow_{t,j}$ refers to the moving average of the differential money flow of the j futures contract in the 10 periods before time t; $I_{t,5,j}$ refers to the moving average of the open position of the j futures contract in 5 periods prior to time t; $\text{Volume}_{t,20,j}$ is the moving average of the trading volume of the j futures contract 20 periods before time t; $I_{t,20,j}$ is the moving average of the closing price of the j futures contract 20 periods prior to time t.

Through the output result of the binary logisitc model, the probability p of the futures contract's rise and fall in the next period is obtained. If the probability value p is greater than 0.5, it is considered that the price of the contract will rise in the next period. At this time, the program will issue a buy order to establish a long position; otherwise, the program will give a short selling order to establish a short position.

4 Data Description and Descriptive Statistics

We provide a descriptive statistical analysis of historical trading data for COMEX Gold Futures (GC) and previous Exchange Gold Futures (AU). The dataset contains the opening, high, low, close, volume, and open interest of two markets, with 2426 observations for each market. Through statistical analysis of these data, we can understand the key characteristics of the market such as volatility, liquidity and activity.

1. Volatility and risk assessment. The standard deviation of GC opening price, high price, low price and close price is around 310, indicating relatively high price volatili-

ty. In terms of price range, the gap between the minimum and maximum values is large, indicating the potential risk and profit space of the market. The standard deviation of AU's opening, high, low and closing prices is about 75, which is lower volatility than GC. The price range also shows a certain amount of risk and return space, but compared with GC, the price fluctuation range of AU in the previous period is smaller.

2. Mobility and activity analysis. The GC volume average shows that the market has some liquidity, but it is less liquid than the previous period. A higher average AU volume indicates good market liquidity and active trading.

3. Position analysis. The average GC position indicates that the average position level of market participants is moderate. The higher average AU holdings may reflect market participants' willingness to invest in gold futures for the long term.

Through descriptive statistical analysis of GC and AU, we can draw the following conclusion: AU's trading activity and liquidity are higher than GC's. The price volatility of GC is higher than that of gold futures in the previous period, which may bring greater risks and benefits. Both markets closed close to their opening prices, showing a regression of prices at the end of the trading day. The average position of the previous period is higher, which may indicate that investors are willing to invest in gold futures for the long term.

5 Money Flows and Commodity Futures Prices

As a technical index, money flow not only reflects the excess supply and demand of the current futures contract, but also has the practical value of reflecting the excess supply and demand of the future futures contract. Because of the short-selling mechanism in the futures market, it is impossible to describe the real law of the money flow of the futures contract directly by using the fund flow formula in the stock market. In this paper, the money flow of futures products is described by considering the comprehensive factors such as the open position and trading volume and the rise and fall of prices. Next, we will quantify the impact of money flow on future commodity futures prices and analyze the sustainability. To examine the correlation between current money flows and future futures prices, we use transaction data from the sample data from 2014 to 2024, and the money flows are calculated by a money flow model constructed based on the futures market. We calculate the correlation coefficient between the money flow series of all futures contracts and the future futures price series, shown in figure 1.

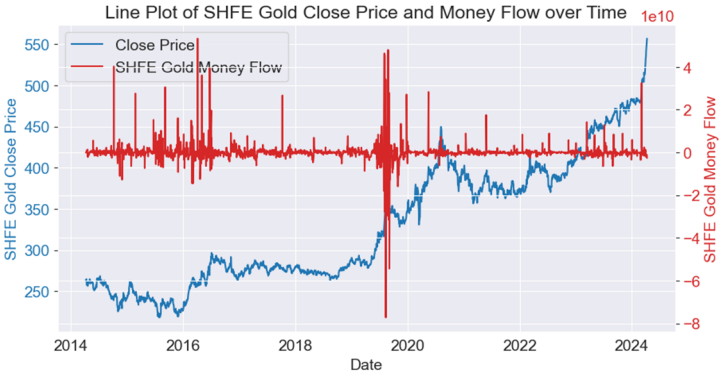

Fig. 1. Relationship between AU futures price and money flow

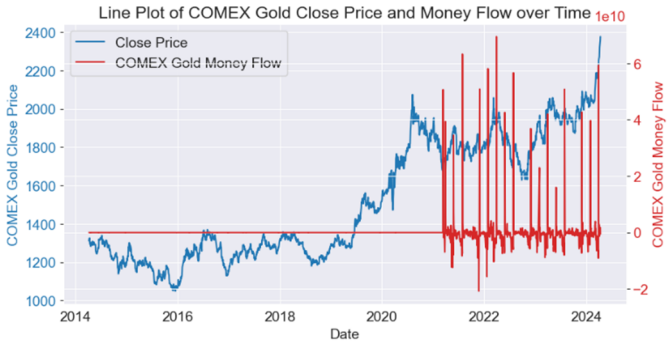

Fig. 2. COMEX gold futures price and money flow relationship

The correlation coefficient between the capital flow of SHFE and COMEX gold futures contracts and future commodity futures is greater than 0.6, shown in figure 2, which indicates that these capital flows are strongly correlated with future commodity futures prices and are positively correlated. However, the impact of the capital flow of the two futures contracts on the future commodity futures prices is different. Therefore, when trading in the futures market, futures contracts with strong positive correlation and futures contracts with negative and positive correlation can be selected to form two portfolios respectively, and the return rate of the futures contracts can be investigated according to their obvious correlation, and then portfolio investment transactions can be carried out. There is a strong correlation between futures contracts. In order to quantify the impact of capital flow on future futures prices, we use linear regression method to obtain quantitative results of the relationship between them. We construct the following regression model : $P_{t,j} = a_0 + a_1 * MoneyFlow_{t,j} + \varepsilon_j$. $P_{t+m,j}$ refers to the closing price of j futures contract at time t; $MoneyFlow_{t,j}$ refers to the standardized money flow of the j futures contract at time t.

Table 1. Relationship between money flow of gold futures contracts and future commodity futures prices

	1day			5day		
	R2	coef	p-value	R2	a	p-value
SHFE	0.47	1.167	0.000	0.21	0.601	0.006
COMEX	0.55	3.527	0.000	0.34	1.211	0.000

Notes:

[1] R^2 is computed without centering (uncentered) since the model does not contain a constant.

[2] Standard Errors assume that the covariance matrix of the errors is correctly specified.

As shown in Table 1, the linear regression results of the two gold futures contracts show that the explanatory degree is greater than 0.4, the regression coefficients are positive, and the corresponding P-values are close to 0, indicating that the gold futures contracts in the two markets have a strong correlation, the money flow is positive, and the price of the future commodity futures contracts rises, and the money flow is positive.The strong correlation between money flow and future prices over a 1-day horizon suggests that short-term trading strategies can effectively capitalize on money flow signals.Traders can use the money flow model to predict price movements within a single trading day, generating buy or sell signals based on the direction and magnitude of money flow.The higher coefficient for COMEX (3.527) compared to SHFE (1.167) indicates that money flow has a more pronounced impact on price movements in the COMEX market, making it a more attractive market for short-term trading.The weaker but still significant correlation over a 5-day horizon suggests that medium-term trading strategies can also benefit from money flow analysis, albeit with reduced predictive power.Traders can use the money flow model to identify trends over a 5-day period, adjusting their positions based on the direction of money flow.The higher R^2 value for COMEX (0.34) compared to SHFE (0.21) indicates that money flow remains a more reliable indicator for medium-term trading in the COMEX market.The autocorrelation analysis reveals that the capital flow direction has a positive correlation persistence within 10 lag periods. This suggests that money flow trends tend to persist over short time horizons, further supporting the use of money flow as a predictive indicator in trading strategies.

6 Quantitative Trading Strategies Based on Money Flows

Based on the above analysis of fund flows, we backtest trades with 1 million Dollar demo accounts. We selected SHFE gold futures and COMEX gold futures from January 1, 2021 to December 31, 2021 to train a binary Logistic regression model, which will be used to predict the future rise and fall of futures prices. The trading signal is generated by the output result of the binary Logistic model, that is, the probability value p of the rise and fall of the futures contract in the next period. If p is greater than 0.5, the price is predicted to rise and a buy signal is issued. If p is less than 0.5, the price is predicted to fall and a short sale signal is issued. Then we selected January

1, 2022 to December 31, 2023 for sample backtesting. The key performance indicators are reported in Table 2. There is a certain degree of similarity between the closing price and the opening price of both markets, indicating a regression phenomenon at the end of the trading day, in addition, the average level of gold holdings in the previous period is higher, which may indicate that investors are willing to invest in gold futures for the long term.

Table 2. Key Performance Indicators

	Cumulative Return	Max Drawback	Cumulative Return with transaction cost	Sharpe Ratio	Sortino Ratio	Information Ratio
SHFE	45.3%	7.8%	42.1%	1.45	2.1	0.2
COMEX	51.2%	6.7%	47.3%	1.56	2.26	0.22

Table 2 reports the key performance of our money flow model on SHFE and COMEX gold futures,which achieved relatively good results, suggesting that 42.1% and 47.3% cumulative return with transaction cost. The out of sample backtest results suggest that Sharpe ratios are 1.45 and 1.56, respectively, indicating that our models are insightful and may be generated in the futures real trading. These results can also be verified by Sortino ratio.

The money flow strategy is more adaptive to changing market conditions, as it dynamically adjusts based on capital flow signals. Mean reversion strategies and trend following strategies may struggle in markets with strong trends or structural breaks. Compared to popular machine learning model, the money flow strategy is simpler and more interpretable compared to machine learning models, which often act as "black boxes." The strategy adapts to changing market conditions by continuously monitoring key risk indicators, such as volatility, open interest, and money flow. For example, if the money flow signals indicate a potential market reversal, the strategy may reduce exposure or exit positions entirely.During a period of high market volatility, the money flow model detects a significant outflow of capital from gold futures, signaling a potential price decline. The strategy reduces position sizes and implements a tighter stop-loss mechanism (e.g., 3% instead of 5%) to protect against further losses. Once the market stabilizes, the strategy resumes normal trading.

The money flow strategy was also tested on crude oil futures (WTI and Brent) from 2021 to 2023. The cumulative returns were 38.5% for WTI and 40.2% for Brent, with Sharpe ratios of 1.32 and 1.38, respectively.The strategy performs well in energy markets, where capital flows are highly influential due to geopolitical and macroeconomic factors.

7 Conclusions

Through the analysis of this paper, we can see that the quantitative trading strategy based on capital flow is a comprehensive system that combines market analysis, statistical modeling and risk management, and has achieved good results in gold futures. However, this paper only gives a trading perspective from the perspective of capital

flow, and in actual operation, strict risk control and continuous strategy optimization are needed to adapt to the ever-changing market environment.

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