Research on Forecasting the Yield of China's Commodity Futures Market Based on the Intraday Momentum Effect

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Abstract. By exploring the intraday momentum effect of the Chinese commodity futures market, it was found that there is a significant intraday momentum effect in the Chinese commodity futures market. The first half hour return of night opening and the first half hour return of day opening can significantly predict the first half hour return of closing within and outside the sample. Furthermore, it was found that the momentum effect of commodity futures is more significant at high trading volume and high volatility levels. The momentum strategy constructed based on the intraday momentum effect can significantly outperform the benchmark strategy, providing investors with a robust investment strategy.

Keywords: Commodity futures market, intraday momentum effect, momentum strategy, volatility.

1. Introduction

The futures market in China emerged in the late 1980s. With the gradual deepening of reform and opening up, the pricing system is gradually being relaxed. At this point, it is difficult to meet the needs of both supply and demand for forward price information without addressing the lag issue of price regulation. In May 1988, the State Council decided to pilot the futures market. On October 12, 1990, with the approval of the State Council, the Zhengzhou Grain Wholesale Market in China officially introduced a futures trading mechanism based on spot trading. As the first commodity futures market in China, it took the first step in the development of China's futures market. In the mid-1990s, the development of China's futures market reached a "small climax". However, due to people's cognitive biases, especially driven by departmental and local interests, and the lack of unified management and sound regulations, the Chinese futures market has shown a blind and rapid development trend. By the end of 1993, there were over 50 futures exchanges and over 300 futures brokerage companies in China, and there were not many types of futures concurrent institutions. This unconventional development has also brought a series of problems to the futures market, such as: excessive number of exchanges, severe duplication of trading varieties, non-standard operation of futures institutions, rampant underground futures trading, mixed professionals, and mixed good and bad. These have seriously hindered the further development of China's futures market and led to various misunderstandings about the futures market. In order to curb the blind development of the futures market, the State Council authorized the China Securities Regulatory Commission to carry out a large-scale clean-up, rectification, and structural adjustment of the futures market entities starting from 1993. By the end of 1999, after seven years of cleaning and rectification, various measures had been basically implemented, regulatory efficiency had significantly improved, and market order had become normal. After cleaning, rectification, and structural adjustment. The three futures exchanges in Shanghai, Dalian, and Zhengzhou have been retained due to their relatively standardized management and stable operation. More than 150 futures brokerage companies have undergone the final capital increase review and are able to continue engaging in futures brokerage business qualifications. At the same time, after qualification exams and recognition, a team of practitioners with futures industry qualifications has emerged. And on December 28, 2000, the China Futures Industry Association, an industry self-discipline organization, was established, marking that China's futures industry has officially become a whole with self-discipline management functions. At this point, after ten years of development, the main structure of China's futures market has tended to improve, and a relatively independent futures industry has basically formed.

Over the past thirty years, the futures market in China has gone through four periods, from the initial exploration period to the rectification and governance period, to the standardized development period, and now to the innovative development period. The futures market in China has become a relatively mature and large-scale market. At present, there are mainly three major exchanges: Shanghai Futures Exchange (SHFE), Dalian Commodity Exchange (DCE), and Zhengzhou Commodity Exchange (CZCE), with a total of 71 trading varieties. As of the end of 2022, Zheng Shang Exchange, Da Shang Exchange, and Shanghai Futures Exchange ranked 8th, 9th, and 12th in global futures and options trading volume, respectively. In 2022, the futures market operated smoothly, and although the trading volume decreased compared to the previous year, it continued to have a relatively large scale since 2020. Among them, the trading volume of commodity futures and option varieties accounted for 72.3% of the global total. In the global trading volume rankings of agricultural products, metals, and energy, domestic futures and options varieties occupy 16, 14, and 5 positions respectively in the top 20 global trading volume rankings of corresponding categories. New varieties are steadily increasing, the derivative system is becoming more perfect, and the capital strength of futures companies continues to strengthen. The futures market is playing an increasingly important role in the financial market. The commodity futures market is constantly expanding the breadth and depth of its opening up to the outside world. Currently, China has opened 23 specific futures varieties to overseas traders and 39 commodity futures and options varieties to QFII and RQFII. Among them, the proportion of primary products reached 96% and 70% respectively. In the later stage, we will continue to steadily expand the opening up of specific futures varieties, expand the investment scope of QFII and RQFII, attract more foreign institutions to fully participate in the pricing of China's primary product futures varieties, enhance the representativeness and influence of China's futures prices, and provide more accurate price information for industrial enterprises. With the gradual opening of the commodity futures market, it will bring more investors and capital, so predicting the yield of the commodity futures market has become more important. Secondly, as the commodity futures market gradually opens up, market trading will also become more active. For academic researchers, the commodity futures market will also become a more worthy research object.

The commodity futures market is a derivative market based on the spot market, which has the following functions in stabilizing and promoting market economy development: (1) the function of avoiding price risks. The most prominent function of the futures market is to provide producers and operators with means to avoid price risks. That is, producers and operators use hedging business in the futures market to avoid the risks caused by price fluctuations in spot transactions, lock in production and operating costs, and achieve expected profits. That is to say, the futures market has made up for the shortcomings of the spot market; (2) The function of discovering prices. Under market economy conditions, prices are formed based on market supply and demand conditions. Traders from all directions in the futures market bring a large amount of supply and demand information, and the transfer of standardized contracts increases market liquidity. The prices formed in the futures market can truly reflect the supply and demand situation, while also providing reference prices for the spot market, playing the role of "discovering prices"; (3) Beneficial to the stability of market supply and demand and prices. Firstly, the futures market trades futures contracts that are expected to be executed at a certain time in the future. It can guide the production and demand of goods by allowing both buyers and sellers of goods to anticipate their future supply and demand based on futures prices before a production cycle begins, playing a stabilizing role in supply and demand. Secondly, due to the intervention of speculators and multiple transfers of futures contracts, the price risks that should be borne by both buyers and sellers are evenly distributed among the numerous traders participating in the trading, reducing the magnitude of price fluctuations and the risks borne by each trader. Since 2016, the futures market has explored the use of a "insurance+futures" model and various futures derivative tools to transfer price risks faced by producers to the futures market. Therefore, investors participating in commodity futures trading can avoid price risks by buying or selling corresponding futures contracts and earn profits by using price differences. With the continuous improvement of relevant policies and regulations in the commodity futures market, including more commodity futures, more and more investors are entering the market for investment. Based on this, accurately predicting the return rate of the commodity futures market is very important for investors and academic researchers.

Unlike stock market trading, commodity futures trading implements a margin system, which means that traders need to pay a small amount of margin when conducting futures trading, usually 5% -10% of the value of the transaction contract, which can complete several times or even tens of times the contract trading. Therefore, this characteristic of futures trading attracts a large number of speculators to participate in futures trading. If traders suffer serious losses and the margin account funds are insufficient, Traders are required to make additional margin calls before the next day's market opening, in order to settle their daily profit and loss situation after each trading day, and transfer funds between different traders based on their profit and loss. In addition, the commodity futures market implements two-way trading, which allows short selling and buying, and implements a T+0 trading system. Many traders are short-term traders who can enhance market liquidity and bear the risk of hedging transaction transfer. Compared to the stock market, the commodity futures market is also a worthy research object.

We are familiar with the fact that the development history of the stock market is longer than that of the commodity futures market, and the trading system is more complete. Relevant research on stock market returns is also more abundant than that of the commodity futures market. At the same time, the stock market also has functions such as risk avoidance and price discovery, so research methods used in the stock market can be used to predict the returns of commodity futures markets. Since Jegadeesh and Titman (1993) first discovered the momentum effect in their exploration of returns in the US stock market, which means that past market performance trends will continue for a period of time in the future, and those with high returns in the past may still have high returns in the future. This provides a new perspective for investors and academic researchers to explore the prediction of financial market returns. Based on this, researchers from various countries have conducted different explorations and found that there is a significant momentum effect in the stock market. With the development and improvement of the commodity futures market, researchers have also applied corresponding methods to explore the return rate of the commodity futures market, and found that there is also a general momentum effect in the commodity futures market. In the past, most studies on the returns of commodity futures markets have found momentum effects on an annual, monthly, and quarterly basis. Nowadays, with the development of science and information technology, we have made significant progress in our ability to obtain data, enabling us to obtain high-frequency data of 10 minutes, 5 minutes, and 1 minute within a day. The exploration of momentum effects has shifted from annual, monthly, quarterly, and daytime to the exploration of intraday momentum effects. Based on this, this article uses high-frequency data of 1-minute commodity futures to divide the commodity futures market into commodity futures markets with night trading and commodity futures markets without night trading, and explores whether there is intraday momentum effect in the domestic commodity futures market. On the one hand, it can explore whether there is intraday momentum effect in China's commodity futures market, providing reliable suggestions for investors and financial regulators; On the other hand, it can provide a new approach for academic researchers to study the intraday momentum effect of commodity futures markets.

The remainder of the paper is organized as follows. Section 2 describes our data. Section 3 presents the empirical analysis. Section 4 investigates intraday momentum strategy. Section 5 details a series of extensions and robustness checks. Finally, Section 6 concludes.

2. Data

The commodity futures selected in this article have night trading, and the trading time period is 9:00 to 11:30, 13:30 to 15:00, and 21:00 to 23:00. Trading is suspended between 10:15 and 10:30, during which traders can handle transaction settlement, clearing, and other work. The trading time period is shown in Table 3.1. Unlike the stock market, the commodity futures market does not have night trading on the trading day before the holiday, which can result in inconsistent data intervals between day and night trading. Therefore, in the subsequent processing of the obtained data, this article excluded the data from the previous day's trading day. Secondly, in order to maintain a basic consistency with commodity futures without overnight trading, the entire sample time range of commodity futures is 852 complete trading days from August 12, 2019 to June 30, 2023. Finally, this article selects six commodity futures, namely rebar (RB), methanol (MA), glass (FG), cotton (CF), coke (J), and coking coal (JM), to explore the momentum effect. From the perspective of sources, rebar comes from the Shanghai Futures Exchange, methanol, glass, and cotton come from the Zhengzhou Commodity Exchange, and coke and coking coal come from the Dalian Commodity Exchange. From the perspective of variety types, rebar futures belong to metal futures, cotton futures belong to agricultural product futures, methanol futures belong to chemical futures, and glass, coke, and coking coal futures belong to industrial futures.

In addition, according to previous experience, the market usually takes about 30 minutes to digest new information, which is exactly an integer multiple of a trading day in the stock market. Although there is a 15 minute market break between 10:00 and 10:30 in the commodity futures market, when dividing trading day time periods based on half an hour intervals, considering 10:00 to 10:15 as half an hour does not have a substantial impact on the subsequent research in this article. Therefore, when there is night trading, a trading day can be divided into 12 and a half hours, the first half hour, which is the first half hour after the opening of the night market (21:00 to 21:30), and then pushed back in sequence. The fifth half hour, which is the first half hour of the day opening (9:00 to 9:30), and the 12th half hour, which is the first half hour before the closing (14:30 to 15:00).

Then analyze the trading volume of the commodity futures market to facilitate the selection of predictive variables in the following text. According to Zhang et al.(2019) mentioned that the distribution of trading volume in the stock market follows the "U The 'type' phenomenon refers to the average trading volume per half hour within the sample interval. The trading volume in the first half hour after opening and one and a half hours before closing is much higher than the trading volume in other time periods of the same day. Why is it so special in the first half hour and last half hour of the trading day? Because most important economic news information is released before the market opens, there is relatively little significant information in the market, and investors have less significant information in the market At the beginning of information processing, the price difference is relatively high, so the trading volume is relatively high half an hour before the opening. The market usually opens at a different level from the previous trading day's closing price because it reflects new information. Secondly, in the first half hour of the closing day, as investors need to develop new investment strategies based on the closing price, the trading volume in the last half hour is also relatively high. The trading volume of the commodity futures market also has a similar situation. Firstly, this article calculates the average trading volume of the sample time interval from August 12, 2019 to June 30, 2023, with half an hour intervals, for a total of 12 and a half hours. It is found that the distribution of trading volume of commodity futures with night trading presents a "W" shape different from that of the stock market.

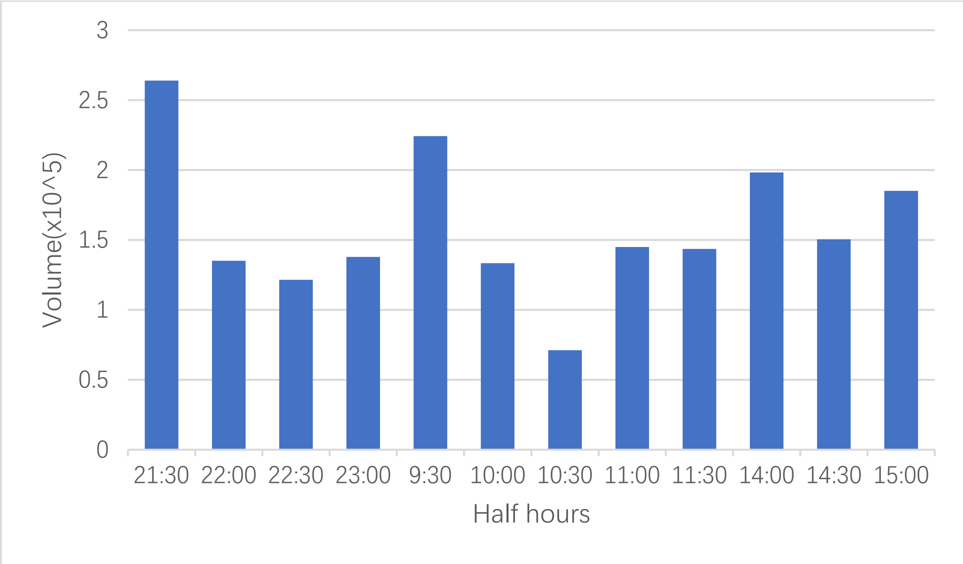

Fig. 1 Distribution of trading volume of rebar in different time periods during the trading day

3. Empirical analysis

3.1.Predictive regression analysis

After selecting the variables mentioned above, this article refers to the method used by Gao et al. (2018) for the intraday momentum effect of high-frequency trading S&P 500 index traded funds (ETFs). Firstly, the yield of commodity futures with night trading is calculated:

$$r_{j,t} = \frac{p_{j,t}}{p_{j-1,t}} - 1, j = 1,...,12 \quad (0.1)$$

Among them, $r_{1,t}$ is the return rate for the first half hour (21:30) of the t-th day (defined as the complete trading day), and so on $r_{12,t}$ represents the yield of the twelfth and a half hour on day t, which is the yield at 15:00. $P_{j,t}$ is the closing price of the jth half hour, $P_{j-i,t}$ is the closing price of the first half hour, and it is worth noting that $P_{0,t}$ is the closing price of the previous trading day, that is, the closing price of the previous day at 15:00, as the initial price for calculating the yield in the first half hour of day t, $P_{0,t} = P_{12,t}$, which allows the first half hour of trading to include information released after the close of the previous trading day.

Referring to Gao et al. (2018), this article uses the following regression model to test the intraday momentum effect in the commodity futures market.

$$r_{12,t} = \alpha + \beta_i r_{i,t} + \varepsilon_t \quad (0.2)$$

Among them, $r_{12,t}$ and $r_{i,t}$ represent the return rate in the 12th half hour of day t and the return rate in the i-th half hour (where i=1, 5, 11), respectively, and are error terms with a mean of zero.

When conducting out of sample testing, it is first necessary to divide the sample interval into two parts: within sample and outside sample. The total sample consists of T observations, which are divided into the within sample part composed of the first m observation value and the outside sample part composed of the last q observation value.

The first out of sample prediction of the twelfth and a half hour yield is:

$$\hat{r}_{12,m+1} = \hat{\alpha}_m + \hat{\beta}_{i,m} r_{i,m+1} \quad (0.3)$$

Among them, $\hat{\alpha}_{i,m}$ and $\hat{\beta}_{i,m}$ are the estimated values of $\{r_{12,t}\}_{t=1}^{m+1}$and $\{r_{i,t}\}_{t=1}^{m+1}$using the least squares method (OLS), with a sample interval of and, where i=1, 5, and 11. Calculate the estimated value of the next sample using the following equation:

$$\hat{r}_{12,m+2} = \hat{\alpha}_{m+1} + \hat{\beta}_{i,m+1} r_{i,m+2} \tag{0.4}$$

among $\hat{\alpha}_{m+1}$ and $\hat{\beta}_{i,m+1}$ is also calculated using the least squares method (OLS) for α and β The estimated value of, but the sample interval used is $\{r_{12,t}\}_{t=1}^{m+1}$ and $\{r_{i,t}\}_{t=1}^{m+1}$. By analogy, continuing in this way until the end of the out of sample interval, we can obtain a series of out of sample predicted values for the twelfth and a half hour return rate $\{\hat{r}_{12,t}\}_{t=m+1}^{T}$.

Next, this article uses out of sample statistics to evaluate the performance of the above prediction models relative to the historical average benchmark. Welch and Goyal (2008) found that many common prediction variables are difficult to exceed the historical average, and the calculation formula for the historical average return rate is $\overline{r}_{12,t+1} = \frac{1}{t\sum_{k=1}^{t} r_{12,t}}$, The calculation formula outside the sample of R^2 is:

$$R_{os}^2 = 1 - \frac{\sum_{t=m+1}^{T} (r_{12,t} - \hat{r}_{12,t})^2}{\sum_{t=m+1}^{T} (r_{12,t} - \overline{r}_{12,t})^2} \tag{0.5}$$

Among them, $r_{12,t}$, $\overline{r}_{12,t}$, $\hat{r}_{12,t}$ are the actual returns, historical average returns, and predicted returns in the twelfth and a half hours of trading day t, respectively, while and are the length of the initial estimation period and the entire sample period.

R_{os}^2 statistics are used to measure the reduction in mean square prediction error (MSFE) of predicted returns relative to the current historical average level. At that time, it indicates that the prediction model proposed in this paper performs better than the prediction of the sample historical mean. Welch and Goyal (2008) proved that it is not an easy task for the predicted value to surpass the benchmark of the sample historical mean, and therefore it is a good indicator of out of sample testing effectiveness, Therefore, this article uses the positive and negative values to preliminarily determine the predictive effect outside of the sample. To further determine whether the predictive model can significantly improve MSFE in statistics, we used Clark and West (2007) statistics (CW statistics) for testing. Specifically, the CW statistic tests the original hypothesis that the MSFE of the benchmark model is less than or equal to the MSFE of the relevant prediction model, as well as the alternative hypothesis that the MSFE of the benchmark model is greater than the MSFE of the prediction model. The definition of CW statistic is as follows:

$$f_t = (r_{12,t} - \overline{r}_{12,t})^2 - (r_{12,t} - \hat{r}_{12,t})^2 + (\overline{r}_{12,t} - \hat{r}_{12,t})^2 \tag{0.6}$$

By regressing $\{f_s\}_{s=m+1}^{T}$ on a constant, we can obtain the CW statistic, which is equal to the t statistic corresponding to the constant. In addition, the values of the one-sided (upper tailed) test can be easily obtained through the standard normal distribution.

Table 1. Intrasample regression analysis of commodity futures

Variables	Name	Time	α	β	r^2 (%)
Rebar	RB	21:30	-0.0002* (-1.4877)	0.0395** (1.8763)	0.50
		9:30	-0.0002* (-1.3463)	0.1317*** (2.4961)	1.01
		14:30	-0.0002* (-1.4149)	-0.0118 (-0.3103)	0.01
Methanol	MA	21:30	-0.0001 (-0.7611)	0.0412 (1.1897)	0.68
		9:30	-0.0001 (-0.7503)	0.0413*** (3.0620)	0.95
		14:30	-0.0001 (-0.6815)	-0.0055 (-0.1417)	0.00
Glass	FG	21:30	0.0001 (0.5444)	0.0353* (1.2905)	0.33
		9:30	0.0001 (0.5818)	0.0497** (1.9590)	0.72
		14:30	0.0001 (0.5919)	-0.0039 (-0.0842)	0.00
Cotton	CF	21:30	0.0001 (1.2343)	0.0492** (2.2020)	1.43
		9:30	0.0001 (1.2598)	0.0101 (0.8240)	0.12
		14:30	0.0001 (1.3505*)	-0.0337 (-0.7764)	0.10
Coke	J	21:30	0.0000 (0.1313)	0.1990*** (2.6169)	2.42
		9:30	-0.0000 (-0.1703)	0.1469** (2.2259)	1.61
		14:30	0.0000 (0.2059)	-0.0618 (-1.2160)	0.27
Coking coal	JM	21:30	0.0002 (0.9047)	0.0000 (-0.0021)	0.00
		9:30	0.0002 (0.7971)	0.0525*** (2.3973)	0.72
		14:30	0.0002 (0.9654)	-0.0959** (-1.9020)	0.66

Note: In the table, ***, **, * respectively represent significant values at 1%, 5%, and 10% confidence levels, with corresponding t-values in parentheses.

From Table1, it can be seen that the intercept terms corresponding to the three time periods of rebar, methanol, glass, cotton, coke, and coking coal are mostly not significant except for rebar. Therefore, this article believes that there is no specific correlation between the intercept terms of the regression and the 12th half hour return rate. From the regression results of the first half hour yield to the 12th half hour yield, the coefficients of rebar, glass, cotton, and coke are 0.0395, 0.0353, 0.0492, and 0.1990, respectively. The regression coefficients are all positive and significant at the 5%, 10%, 5%, and 1% levels, respectively. However, the predictive performance of methanol and coke coal during this time period is not ideal. From the regression results of the 5th half hour yield to the 12th half hour yield, the regression coefficients for rebar, methanol, glass, coke, and coking coal are 0.1317, 0.0413, 0.0497, 0.1469, and 0.0525, respectively, which are significant at the 1%, 1%, 5%, 5%, and 1% levels. Only cotton did not show significant predictive ability during this time period. Unfortunately, from the regression results of the 11th half hour yield to the 12th half hour yield, none of the six commodity futures showed significant predictive power. Therefore, this article believes that there is no specific correlation between the 11th half hour yield and the 12th half hour yield. From the overall regression results, it can be seen that unlike Zhang et al.(2019) who found in the stock market that the second to last half hour before closing can significantly predict the first half hour yield, and Zhang Wei et al.(2020) who also found in the commodity futures market that the second to last half hour before closing can significantly predict the first half hour, the momentum effect only exists between and, and there is no specific correlation between and.

Table 2. Out of sample test results

Variables	Time	R^2_{OS}(%)	p
Rebar	21:30	0.2683	0.1312
	9:30	1.0140**	0.0205
Methanol	21:30	-0.2541	0.3965
	9:30	0.1662	0.1778
Glass	21:30	-0.0251	0.3126
	9:30	0.8052***	0.0053
Cotton	21:30	1.0761**	0.0447
	9:30	-0.1728	-0.5816
Coke	21:30	2.0767***	0.0075
	9:30	1.1493*	0.0605
Coking coal	21:30	-0.6930	0.9444
	9:30	0.5054*	0.0558

Note: In the table, ***, **, * respectively represent significant values at 1%, 5%, and 10% confidence levels, and their significance is based on the p values tested by Clark and West (2007).

From the results of the out of sample test in Table 4.4, we can see that the prediction of the first half hour return rate for rebar and glass is significant within the sample, but unfortunately, these two commodity futures did not pass the out of sample test for prediction; The prediction of the first half hour yield of cotton and coke on the 12th half hour yield not only passed the tests within the sample, but also passed the tests outside the sample. Their values were 1.0761 and 2.0767, respectively, which were significant at the 5% and 1% levels. In the prediction of the 5th half hour return rate and the 12th half hour return rate, not only did rebar, glass, coke, and coke pass the out of sample test, but also the out of sample test, with values of 1.0140, 0.8052, 1.1493, and 0.5054, respectively, which were significant at the 5%, 1%, 10%, and 10% levels. However, methanol that performed well within the sample did not pass the test outside the sample. From the above results, overall, commodity futures also have a certain degree of robustness outside the sample. We can find that the 5th and a half hour yield is more robust in predicting the 12th and a half hour yield than the 1st and a half hour yield.

3.2.The impacts of volatility and volume

Through the previous exploration of momentum effects from both inside and outside the sample, it was found that there is momentum effect in the commodity futures market. Next, this article further explores how momentum effects behave at different volatility levels. Similarly, only the first and a half hour return and the fifth and a half hour return were selected as predictive variables to predict the 12th and a half hour return. The specific results are shown in Table 3:

Table 3. Internal and external test results of samples under different volatility

Variables	Volatility	Time	α	β	r^2 (%)	R_{OS}^2 (%)
Rebar	High	21:30	-0.0004	0.0000	0.00	-1.3259
			(-1.1617)	(0.0174)		(-1.8149)
		9:30	-0.0004	-0.1176**	0.84	1.1392*
			(-1.0845)	(1.6789)		(1.4735)
	Medium	21:30	-0.0003	0.0011	0.26	-0.6264
			(-1,1467)	(0.7264)		(-0.7253)
		9:30	-0.0003	0.0073	0.01	-0.4232
			(-1.0428)	(0.2416)		(-0.9116)
	Low	21:30	-0.0000	0.0011	0.34	-0.5847
			(-0.0989)	(0.9614)		(0.1085)
		9:30	-0.0000	0.0328	0.31	-0.3201
			(-0.1328)	(1.0187)		(0.5493)
Methanol	High	21:30	-0.0002	-0.0017	0.41	-0.0548
			(-0.5090)	(-1.0380)		(0.0961)
		9:30	-0.0002	-0.0433***	1.32	1.3684**
			(-0.6373)	(-3.2637)		(1.7282)
	Medium	21:30	0.0001	-0.0004	0.04	-0.6405
			(0.4779)	(-0.3431)		(-1.3282)
		9:30	0.0001	0.0137	0.06	-0.9318
			(0.4395)	(0.4079)		(-1.0834)
	Low	21:30	-0.0002	0.0005	0.13	-0.5695
			(-0.9219)	(0.5324)		(-1.6429)
		9:30	-0.0002	0.0195	0.17	-0.3646
			(-0.9306)	(0.6989)		(-0.7213)
Glass	High	21:30	-0.0002	-0.0039	2.20	0.4346
			(-0.4322)	(-1.8087)		(1.2235)
		9:30	-0.0003	-0.0218	0.08	-0.5125
			(-0.7536)	(-0.5823)		(-0.8811)
	Medium	21:30	0.0005	-0.0002	0.01	-0.7255
			（1.5827）	(-0.2233)		(-1.3597)
		9:30	0.0005	0.0062	0.02	-0.1917
			(1.5556)	(0.4458)		(-0.7821)
	Low	21:30	0.0002	-0.0020	1.79	0.6848
			(1.2046)	(-1.5068)		(0.9399)
		9:30	0.0002	0.0561	0.82	0.5835
			(0.9082)	(1.6111)		(1.2209)
Cotton	High	21:30	0.0001	0.0016	1.42	0.4655*
			(0.4403)	(2.2170)		(1.2962)
		9:30	0.0002	-0.0148	0.20	-0.8230
			(0.7481)	(-0.7636)		(-1.1528)
	Medium	21:30	-0.0001	0.0013	1.76	0.1942
			(-0.6481)	(2.1723)		(0.8189)
		9:30	-0.0001	-0.0186	0.75	1.3526
			(-0.4503)	(-1.5687)		(1.9407)
	Low	21:30	0.0003	0.0001	0.03	-2.2730
			(1.9829)	(0.2893)		(-1.4144)
		9:30	0.0003	-0.0077	0.03	-0.7931
			(2.0381)	(-0.2605)		(-0.8241)
Coke	High	21:30	0.0002	-0.0041	1.77	1.4598**
			(0.3980)	(-2.1255)		(1.7988)
		9:30	0.0002	-0.1074**	2.42	1.7659*
			(0.3714)	(-2.0387)		(1.5564)
	Medium	21:30	-0.0000	0.0002	0.01	-0.8393
			(-0.0360)	(0.1503)		(-1.1910)
		9:30	-0.0000	-0.0438	0.47	-0.5345
			(-0.0889)	(-1.4278)		(0.0612)

	Low	21:30	0.0000	0.0004	0.04	-1.4855
			(0.1150)	(0.3055)		(-1.1966)
		9:30	0.0000	0.0271	0.30	0.1787
			(0.0684)	(1.1218)		(0.5900)
Coking coal	High	21:30	0.0005	-0.0018	0.54	-3.4748
			(1.0114)	(-1.0793)		(-0.6015)
		9:30	0.0005	-0.1129***	2.82	0.4405*
			(0.8765)	(-3.1463)		(1.5362)
	Medium	21:30	0.0000	-0.0003	0.02	-1.3050
			(0.0860)	(-0.2188)		(-1.4871)
		9:30	0.0000	0.0716	0..02	-1.5369
			(0.0307)	(0.8478)		(-1.7562)
	Low	21:30	0.0002	0.0016***	1.17	0.4722*
			(0.8992)	(2.2500)		(1.6126)
		9:30	0.0003	0.0114	0.08	-0.2779
			(1.1211)	(0.7292)		(-0.0699)

Note: In the table, ***, **, * respectively represent significant values at 1%, 5%, and 10% confidence levels, α，β，The parentheses below the value $R_{os}^2(\%)$ represent the corresponding t-value, while the parentheses below represent the Clark and West (2007) statistic, which is equivalent to the t-value.

From Table3, it can be seen that under these three volatility levels, the results inside and outside the six commodity futures samples are mostly not significant. But we found that at high volatility levels, there was a reversal effect in the prediction of the 5th and a half hour yield for four commodity futures compared to the 12th and a half hour yield. Specifically, the regression coefficients of deformed steel, methanol, coke, and coking coal are all negative, with values of -0.1176, -0.0433, -0.1074, and -0.1129, respectively, which are significant at the 5%, 1%, 5%, and 1% levels; And their $r^2(\%)$ samples were 0.84, 1.32, 2.42, and 2.82 respectively, indicating that the prediction effect was significant throughout the entire sample interval; From the $R_{os}^2(\%)$ perspective, they are 1.1392, 1.3684, 1.7659, and 0.4405, which are significant at 10%, 5%, 10%, and 10%, respectively. All four commodity futures have passed the out of sample test under high volatility, but exhibit a momentum reversal effect. This article aims to explore the intraday momentum effect, and there is no further exploration of the momentum reversal effect in the following text. Researchers interested in the momentum reversal effect in the future can explore the reversal effect that appears in the prediction of the 12th half hour yield using the 5th half hour yield at high volatility levels. In addition, in the prediction of the first half hour yield under high volatility levels and the 12th half hour yield, glass and coke also showed a reversal effect, $r^2(\%)$ reaching 2.20 and 1.77, but the glass $R_{os}^2(\%)$ yield was 0.4346, which was not significant, while the coke $R_{os}^2(\%)$ yield was 1.4598, which was significant at the 5% level; Cotton showed momentum effect in the first half hour, $r^2(\%)$ reaching 1.42, $R_{os}^2(\%)$ is 0.4655, which is significant at the 10% level. At the medium volatility level, only cotton showed momentum effect within the sample, but unfortunately it did not pass the test outside the sample. At low volatility levels, glass exhibits momentum reversal effects within the sample, but it also fails to pass tests outside the sample; Coking coal exhibits momentum effect, which is $r^2(\%)$ 1.17 and $R_{os}^2(\%)$ 0.4722, which is significant at the 10% level.

From the above analysis, it can be seen that the intraday momentum effect is not ideal at medium to low volatility levels. Only at high volatility levels does it show a significant momentum reversal effect. The momentum reversal effect refers to the fact that assets or investment strategies that have performed poorly in the past will have a certain degree of regression or reversal in the future in the financial market. Therefore, it can also be used to formulate investment strategies and risk management to a certain extent, De Bondt et al.(1985) and Chu Xiaojun et al.(2019) found the presence of momentum reversal effect in the stock market, and strategies based on momentum reversal effect can also generate significant returns. Miffre et al. (2007) and Huang Zhuo et al. (2015) also found significant momentum reversal effect in the commodity futures market, and investment strategies based on reversal effect can also bring significant returns. However, this article aims to explore the intraday momentum effect in the commodity futures market, so it does not delve deeper into the momentum reversal effect. Although this article found momentum reversal effect under high volatility, it still believes that higher volatility is more conducive to predicting the returns of commodity futures markets. This is consistent with Wen Danyan et al.(2021) finding that the predictability of intraday reversal is concentrated in periods of high volatility.

In the study of the momentum effect of commodity futures under different trading volume levels, this article found that both commodity futures with and without night trading are in high trading volume trading mode, The first half hour yield of daily trading (the 5th half hour yield with night trading and the 1st half hour yield without night trading) has a significant predictive ability on the 12th half hour yield; No significant predictive ability was found at medium to low trading volume levels. The higher the trading volume level, the better the predictive ability. The specific results and analysis are shown below.

Table 4. Internal and external test results of samples under different volume

Variables	Volatility	Time	α	β	r^2 (%)	R^2_{OS} (%)
Rebar	High	21:30	-0.0005*	0.0002	0.01	-0.4220
			(-1.4574)	(0.1696)		(-1.6783)
		9:30	-0.0005*	0.0962**	1.65	2.1211**
			(-1.5538)	(2.1162)		(1.9378)
	Medium	21:30	0.0001	-0.0035***	3.02	2.5460*
			(0.1928)	(-2.8392)		(1.5199)
		9:30	-0.0000	0.0200	0.01	-0.2698
			(-0.1190)	(0.5586)		(-1.0819)
	Low	21:30	-0.0002	0.0001	0.00	-0.3263
			(-0.8497)	(0.0743)		(-0.7947)
		9:30	-0.0001	-0.0448**	0.70	-3.5244
			(-0.7326)	(-1.8292)		(0.2515)
Methanol	High	21:30	-0.0002	0.0007	0.10	-1.5181
			(-0.7478)	(0.4260)		(-0.5173)
		9:30	-0.0001	0.0707*	0.55	0.9433**
			(0.3460)	(1.3517)		(1.8100)
	Medium	21:30	-0.0002	0.0001	0.01	-0.4818*
			(-0.7425)	(0.1206)		(-1.3319)
		9:30	-0.0002	0.0508	0.69	0.5644
			(-0.8206)	(1.2394)		(1.0612)
	Low	21:30	0.0001	-0.0005	0.07	0.0274
			(-0.4138)	(-0.4976)		(0.4479)
		9:30	0.0001	0.0152*	0.41	-6.2156
			(0.3579)	(1.5590)		(1.5771)
Glass	High	21:30	0.0006**	-0.0001	0.00	-0.4103
			(1.8661)	(-0.0644)		(-0.3581)
		9:30	0.0006**	0.0439	0.39	0.1452
			(1.8551)	(0.9792)		(0.7656)
	Medium	21:30	-0.0002	0.0013	0.43	-1.2129
			(-0.5297)	(1.1263)		(0.7585)
		9:30	-0.0001	-0.0074	0.01	-1.1884
			(-0.3670)	(-0.1516)		(-1.7481)
	Low	21:30	-0.0001	0.0004	0.04	-2.0890
			(-0.4110)	(0.3475)		(-0.2749)

		9:30	-0.0001	0.0048	0.01	-5.1924
			(-0.3671)	(0.2646)		(-2.0484)
Cotton	High	21:30	0.0001	0.0012*	0.52	0.3669
			(0.7274)	(1.3132)		(0.9100)
		9:30	0.0001	0.0178	0.25	-0.7876
			(0.8087)	(0.9023)		(-0.5388)
	Medium	21:30	-0.0001	0.0010**	0.90	0.2620
			(-0.5287)	(1.6528)		(1.2635)
		9:30	-0.0001	0.0062	0.03	-0.7948
			(-0.3492)	(0.2928)		(-1.4903)
	Low	21:30	0.0003**	-0.0006*	0.74	-0.6272
			(1.8981)	(-1.4105)		(0.5732)
		9:30	0.0002**	0.0107*	0.32	0.3390
			(1.7069)	(1.5823)		(1.2640)
Coke	High	21:30	-0.0002	-0.0011	0.24	-0.2479
			(-0.4995)	(-0.8170)		(-0.5497)
		9:30	-0.0003	0.0766**	1.09	0.7288*
			(-0.7329)	(1.7295)		(1.3042)
	Medium	21:30	0.0002	-0.0004	0.03	-0.5262
			(0.4553)	(-0.3848)		(-0.8928)
		9:30	0.0001	0.0033	0.01	-0.2743
			(0.4128)	(0.1518)		(0.0658)
	Low	21:30	0.0001	-0.0000	0.00	-0.4722
			(0.1593)	(-0.0078)		(-0.4462)
		9:30	0.0001	0.0101	0.02	0.0531
			(0.1574)	(0.2921)		(0.8684)
Coking coal	High	21:30	0.0003	0.0005	0.07	-0.7019
			(0.8456)	(0.5249)		(-1.5964)
		9:30	0.0003	0.1216**	0.88	1.7655*
			(0.9742)	(2.1032)		(1.3959)
	Medium	21:30	-0.0001	0.0001	0.00	-1.2004
			(-0.2093)	(0.0611)		(-2.2200)
		9:30	-0.0001	0.0873**	1.44	0.6212*
			(-0.1155)	(2.1092)		(1.5521)
	Low	21:30	0.0003	0.0005	0.14	-0.4150
			(0.7585)	(0.6654)		(-0.0467)
		9:30	0.0003	0.0458**	0.73	0.2917**
			(0.8676)	(2.0263)		(2.0709)

Note: In the table, ***, **, * respectively represent significant values at 1%, 5%, and 10% confidence levels, α，β，The parentheses below the value $R_{os}^2(\%)$ represent the corresponding t-value, while the parentheses below represent the Clark and West (2007) statistic, which is equivalent to the t-value.

4. Intraday momentum strategy

After the empirical analysis in the previous section, it was found that there is a significant intraday momentum effect in the Chinese commodity futures market. In addition, the performance of the intraday momentum effect under different trading volumes and volatility levels was also explored. It was found that momentum reversal effect is more prevalent at high volatility levels, and there is a significant momentum effect at high trading volume levels. The intraday momentum effect predicts the future based on historical information, so it is worth further exploring whether the momentum effect can help investors obtain excess returns in the commodity futures market. In response to this issue, this article further explores the application of momentum effects in the commodity futures market. Momentum strategy is to use the first half hour yield, the fifth half hour yield, and both the first half hour yield and the fifth half hour yield as strategy signals, according to the strategic signal, establish long or short positions accordingly half an hour before the closing, and close out positions at the end of each trading day. The specific strategy model is as follows:

Strategy 1: Use the first half hour yield as the strategy signal. When it is greater than or equal to 0, enter the market for long trading half an hour before the close, and close the position before the close. Otherwise, enter the market for short trading half an hour before the close, and close the position before the close.

$$f_{(r_1)} = \begin{cases} r_{12} & r_1 \geq 0 \\ -r_{12} & r_1 < 0 \end{cases}$$

Strategy 2: Use the 5th and a half hour yield as the strategy signal. When it is greater than or equal to 0, enter the market for long trading half an hour before the close and close the position before the close. Otherwise, enter the market for short trading half an hour before the close and close the position before the close.

$$f_{(r_5)} = \begin{cases} r_{12} & r_5 \geq 0 \\ -r_{12} & r_5 < 0 \end{cases}$$

Strategy 3: Joint strategy, while using the first half hour yield r_ Return rate r for the first and fifth half hours_ As a strategy signal, when r_ 1 and r_ When 5 is greater than or equal to 0 at the same time, enter the market for long trading half an hour before the closing, and close the position and leave the market before the closing; When r_ 1 and r_ When 5 is less than 0 at the same time, enter the market for short trading half an hour before closing, and close the position and leave the market before closing; In other cases, if the trading conditions are not met, no trading will be conducted today.

$$f_{(r_{joint})} = \begin{cases} r_{12} & r_1 \geq 0 \ \ and \ \ r_5 \geq 0 \\ -r_{12} & r_1 < 0 \ \ and \ \ r_5 < 0 \\ 0 & else \end{cases}$$

Strategy 4: Benchmark strategy($f_{(r_{AL})}$), which involves entering for long trading half an hour before the close of each defined full trading day, and closing and exiting before the close, to measure the performance of the constructed momentum strategy.

In actual trading, there are transaction costs in the commodity futures market. David A Lesmond et al. (2004)proposed that momentum profits may still be eroded by transaction costs or may be a compensation for light trading and market friction. Therefore, this article further explores whether momentum effects can provide reference for investors while considering transaction costs. There are two transactions on a complete trading day, one for entering the market half an hour before closing and the second for closing and leaving the market before closing. Each transaction will have a transaction fee calculated. The commodity futures explored in this article come from three major exchanges, with different trading markets and different standards for trading fees. The trading fees for different commodity futures are also different, and the trading fees for opening and closing positions are also different. If calculated based on different transaction fees for each commodity futures, it will become more complex. The purpose of this article is to explore the changes in strategy performance after introducing transaction fees. Therefore, this article selects the transaction fee of 2017 rebar 5% as the transaction fee for the studied commodity futures.

Table 5. Momentum strategy results

Variables	Timing strategy	Average yield (%)	Standard deviation (%)	Sharpe ratio
Rebar	$f_{(r_1)}$	4.5804	0.4589	3.9871
	$f_{(r_5)}$	5.1261	0.4587	4.4642
	$f_{(r_{joint})}$	4.0989	0.3296	4.9669
	$f_{(r_{AL})}$	-8.1739	0.4592	-7.1262
Methanol	$f_{(r_1)}$	4.3345	0.4659	3.7156
	$f_{(r_5)}$	2.5053	0.4663	2.1435
	$f_{(r_{joint})}$	4.0635	0.3025	5.3649
	$f_{(r_{AL})}$	-5.2072	0.4666	-4.4695

Glass	$f_{(r_1)}$	1.0200	0.5486	0.7389
	$f_{(r_5)}$	1.6192	0.5486	1.1759
	$f_{(r_{joint})}$	1.0382	0.3354	1.2302
	$f_{(r_{AL})}$	0.3174	0.5487	0.2266
Cotton	$f_{(r_1)}$	-4.3694	0.2824	-6.1971
	$f_{(r_5)}$	-0.0974	0.2824	-0.1472
	$f_{(r_{joint})}$	-2.5676	0.2120	-4.8566
	$f_{(r_{AL})}$	0.4842	0.2823	0.6768
Coke	$f_{(r_1)}$	10.4174	0.6532	6.3748
	$f_{(r_5)}$	4.1433	0.6547	2.5272
	$f_{(r_{joint})}$	6.1629	0.4117	5.9813
	$f_{(r_{AL})}$	-1.7349	0.6553	-1.0630
Coking coal	$f_{(r_1)}$	5.7636	0.7085	3.2505
	$f_{(r_5)}$	4.5964	0.7087	2.5907
	$f_{(r_{joint})}$	5.5321	0.5055	4.3722
	$f_{(r_{AL})}$	2.9944	0.7089	1.6859

From Table5 above, it can be seen that during night trading, in addition to poor performance of cotton, the remaining commodity futures such as rebar, methanol, glass, coking coal, and coke can still significantly outperform the benchmark strategy in strategies one to three, after considering transaction costs. Therefore, r_1,r_5,or $r_1$and r_5 as a signaling strategy, can bring significant returns to investors.

5. Conclusion

Firstly, this article tests the momentum effect within the entire sample range of commodity futures. The selected three and a half hour returns, namely the first half hour return after the opening of the night market, the first half hour return after the opening of the day market, and the impact of the second to last half hour return before the closing on the first half hour return, include rebar, glass, and cotton, Four varieties of coke showed momentum effect in the first half hour of night trading, while five varieties of rebar, methanol, glass, coke, and coking coal showed momentum effect in the first half hour of day trading, and there was no significant momentum effect in the penultimate half hour. Overall, there is an intraday momentum effect in the commodity futures market, and the momentum effect performs better in the first half hour of the day.

Then this article explores the performance of intraday momentum effects in commodity futures markets at different volatility levels and trading volume levels. We found that only under high volatility, there is significant predictability in the first half hour after the opening of the day. Unfortunately, there is a momentum reversal effect, which has not been further explored in this article. Under different trading volumes, the yield of rebar, methanol, coke, and coking coal in the first half hour of daily trading can significantly predict the yield in the last half hour under high trading volumes. Overall, commodity futures exhibit more significant predictive power under high volatility and high trading volume, with greater volatility leading to stronger predictive power. We also conducted tests outside of the sample, and those that performed well within the sample passed the tests outside of the sample. Therefore, our prediction ability is robust under high volatility.

Finally, considering whether the intraday momentum effect can bring more utility to investors, a momentum strategy was constructed, using the benchmark strategy as a measurement indicator. After considering transaction costs, we found that the momentum strategy did not change and could bring significant returns to investors. Overall, momentum strategies can bring more significant returns to investors.

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