Influencing Factors of Aluminum Futures Price and Forecast Arbitrage

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Abstract: With the rapid development of China’s social economy, the development of related industries has driven the rapid growth of aluminum consumption. As the second largest metal, aluminum products have been integrated into real life and widely used in aerospace, construction, transportation, electricity, packaging and other fields. This paper takes Shanghai Aluminum Continuous Futures (AL7777) as an example to study its influencing factors and arbitrage possibilities.

Keywords: Aluminum Futures; Simultaneous Equation Model; AR Model; Cross-Commodity Arbitrage

1. Basic information

1.1 Aluminum production

Aluminum or aluminum alloy is currently one of the most economical and practical materials. In the past three years, the output and consumption of aluminum has increased steadily and it is in short supply, which has an important impact on the global economic development. The output and consumption of alumina and electrolytic aluminum in China account for 35% to 40% in the world. The total scale of aluminum industry is the largest in the world, and it is a large manufacturing and consuming country in the aluminum industry[1].

1.2 Domestic and international situation

1.2.1 International market

Bauxite that mainly distributed in Guinea, Australia, Vietnam, Brazil, Australia, South America, and Africa have better bauxite quality, large reserves and low mining cost[2]. Due to the high dependence of electrolytic aluminum production on alumina raw materials, the factories are mostly distributed in the vicinity of regions with rich bauxite resources. In addition, about 80% to 90% of alumina in the world is sold through long-term contracts, which is rarely available for spot market transactions.

1.2.2 Domestic market

China’s bauxite reserves rank seventh in the world, but the aluminum-silicon ratio is low. The production process is complex and the mining cost is high[3]. China’s alumina output rose from less than 1 million tons in the 1990s to 19.18 million tons in 2007, and its consumption rose from 830,000 tons in 1990 to 12.05 million tons in 2007. China’s alumina production has increased significantly, which has caused the global alumina price that rose for many years drop significantly, greatly reducing the cost of domestic electrolytic aluminum production enterprises[4].
2. Factors affecting aluminum futures price

2.1 Supply and demand relations

With the growth of global aluminum consumption, the price of original aluminum has risen sharply since 2001. Because of the dramatically increase in demand for aluminum caused by economic growth in China and other emerging economies, global aluminum consumption rose from 24.6 million tons in 2000 to 46.61 million tons in 2012.

2.2 Electricity cost

At present, thermal power is still the main source of electricity in China. The cost is only 0.3 to 0.4 yuan per kilowatt hour. Electricity is the necessary energy in the aluminum production process. The rise of electricity price directly affects the production cost of aluminum and leads to the shutdown and production reduction of some enterprises. However, only when the market supply is reduced can the price of electrolytic aluminum rise.

2.3 Inventory

Inventory can indirectly reflect the situation of market consumption and the degree of spot trading. The economic relationship between inventory and price is positively correlated, and rising prices leads to increased inventories and vice versa.

2.4 Output

Aluminum output and price fluctuation have an interactive relationship, and output change has a lag effect on price change. Price increase stimulates output growth, but output growth often lags behind price increase. For example, when prices rise to the highest point, output growth doesn’t reach the highest point at the same time, but only after a period of delay[5].

2.5 Impact of substitutes-copper price

As the earliest metal used by human beings, copper is widely used in many fields. As a substitute, copper price has an important influence on aluminum price. Copper price rise leads to a decrease in consumer demand and an increase in aluminum demand.

The increase in aluminum demand drives up aluminum price, resulting in an increase in aluminum production. To some extent, there is a positive correlation between copper price and aluminum price.

3. Simultaneous equation model and prediction

3.1 Simultaneous equation modeling

3.1.1 Concept of simultaneous equation model

Simultaneous equation model is a system of equations that describes the simultaneous dependency between variables. There is a complex causal relationship between the relevant variables of the influencing factors of aluminum price. Therefore, simultaneous equation model is adopted to explore the relationship between aluminum price and influencing factors[6].

3.1.2 Identification of simultaneous equation models

Identification of simultaneous equation models can be divided into three situations: insufficient identification, just identification, and over-identified. The identification order condition is: \( K-k \geq M-1 \) (K is the total number of variables in the equation, k is the number of variables in the equation, and M is the number of equations). Establish simultaneous equations:

\[
P_t = \alpha_0 + \alpha_1 Q_t + \alpha_2 R_{t-1} + \alpha_3 T_{t-1} \\
Q_t = \beta_0 + \beta_1 P_t + \beta_2 N_t
\]

The data is from March 2016 to December 2018. \( P_t \) is the monthly time series data of aluminum futures index.
is the monthly time series data of aluminum demand (ten thousand tons); \( R_t \) is the monthly time series data of aluminum stock (ten thousand tons); \( T_t \) is the monthly time series data of copper output (ten thousand tons); \( N_t \) is the monthly time series data of industrial electricity price (Yuan/kWh).

In the simultaneous equation model, the total number of variables \( K=5 \) and the total number of equations \( M=2 \), so equation (1) is just identified. Equation (2) overidentified.

### 3.1.3 Parameter estimation of simultaneous equations

Used the two-stage least square method to estimate the parameters of equations (1) and (2), the regression estimation formula is as follows:

\[
R_t=2040.712+13.704Q_t+2.151R_{t-1}+0.106T_{t-1}
\]

\[
Q_t=1003.103+0.017P_t-1192.244N_t
\]

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\]

The estimation results of the simultaneous equations show that price and output are mutually influencing factors, and the futures price of aluminum mainly depends on the output, the previous issue of inventory and the previous issue of copper price. With other factors unchanged, the price of aluminum increases by 13.704 yuan for every 10,000 tons of output increase. With other factors unchanged, the price of aluminum increased by 2.151 yuan for every 10,000 tons of inventory increase in the previous issue of period. With other factors unchanged, the price of aluminum increased by 0.106 yuan for every rise in copper price in 1 yuan in the previous issue of period.[7]

### 3.2 Aluminum price forecast and analysis

Prediction is an important part of econometric analysis. Time series prediction refers to arranging the obtained data into a sequence according to the time sequence, and analyzing its direction and degree of change to speculate on the level that may be reached in the next several periods. The basic idea is to take the time series as a sample of random variables, and to reduce the influence of accidental factors as much as possible through the method of probability statistics.

#### 3.2.1 Unit root test of sequence \( P \)

The graph of sequence \( P \) drawn by Eviews software shows that sequence \( P \) has no trend of change with time. Therefore, the equation doesn’t contain time trend term. The statistic of ADF test \( T \) value is -6.149, which is less than the critical value, and the corresponding probability value of \( T \) statistic is 0.0001. It is a small probability event, so sequence \( P \) is considered stable.

#### 3.2.2 Establishment of autocorrelation function

Eviews correlation analysis chart shows autocorrelation tailing and partial correlation truncation. Selected AR model and appropriately expand the range of orders. The results show that AIC, SC and HQC values of AR(1) are less than the corresponding values of AR(2) and AR(3). So AR(1) model is selected. Similarly, ARCH(1) is selected for heteroscedasticity test, and the \( P \) value is 0.9618, so there is no ARCH effect, that is, there is no heteroscedasticity. The AR(1) model obtained through inspection is as follows: \( P=3851.148+0.728P(-1) \).

Judging from the regression equation, every change in 1 yuan of aluminum price in the previous issue results in a change of 0.728 yuan in the next issue.

Through the simulation of historical data, compared the predicted price with the actual value, there is somewhat different, but the overall prediction effect is good.

### 4. Copper-aluminum arbitrage

#### 4.1 Basic relationship between copper and aluminum
Supply and demand are important factors that determine the price of copper and aluminum. With economic prosperity and increased demand, copper and aluminum prices rise. Copper and aluminum have high substitutability, and there is a certain relationship between the price fluctuation of them. In the short term, one price goes up and the other goes down. But from the long-term trend, copper and aluminum have high correlation, common price influencing factors and active transactions, so there may be arbitrage opportunities between them⁹.

4.2 Empirical analysis

4.2.1 Copper and aluminum price correlation test

Based on the monthly K-line chart of Shanghai Copper Continuous Futures (CU7777) and Shanghai Aluminum Continuous Futures (AL7777) closing prices from January 2007 to December 2018, the price trend of copper and aluminum is basically the same, indicating that arbitrage between copper and aluminum is highly feasible.

In order to further prove that there is a long-term stable equilibrium relationship between the two, the daily closing prices data of Shanghai Copper Continuous Future and Shanghai Aluminum Continuous Futures from March 1, 2016 to December 31, 2018 are selected as the research objects, and the variables are analyzed quantitatively. If there is a cointegration relationship, there is a long-term stable equilibrium relationship between them, which can be arbitraged.

Before testing the cointegration relationship of variables, ADF testing on the data was conducted. The results show that F value equal to -17.23 in the aluminum price less than T value, and F value equal to -27.43 in the copper price ADF less than T value, both of which are stable in the first-order difference sequence.

Co-integration test was conducted by EG test method, and equation was obtained by OLS regression:

\[ P = 6545.879 + 0.1578T + \mu \]

\[(196.578) \quad (0.004)\]

ADF test is performed on the residual sequence. At this time, the statistical value of the ADF test is -26.1923, which is less than the critical value. The residual sequence is stable, so there is a cointegration relationship between the closing prices of Shanghai Copper Continuous Futures and Shanghai Aluminum Continuous Futures.

4.2.2 Correlation between copper and aluminum prices

In OLS of aluminum price to copper price, T value is significant, which indicates that Shanghai Copper Continuous has significant explanatory significance to Shanghai Aluminum Continuous⁹. The sequence of closing prices of copper and aluminum is first-order single integration in a cointegration relationship, which shows that there is a long-term stable equilibrium relationship between the two, and the two commodities have strong correlation and high liquidity, so cross-commodity arbitrage between copper and aluminum is feasible.

4.3 Arbitrage opportunities and conclusions

Scatter chart of copper and aluminum prices is analyzed. It is feasible to strategically choose to buy copper and throw aluminum or buy aluminum and throw copper. As shown in the following figure: in Point A, copper price is underestimated relative to aluminum, so sell aluminum to buy copper; in Point B, copper price is overvalued relative to aluminum, so sell copper to buy aluminum; in Point C, aluminum price returns to a reasonable position and continues to hold positions on copper⁹.

When the price difference between the two is larger than the average value, both sides enter the market, and when the price difference returns to a reasonable level, both sides withdrawal from the market. The opportunity of high throw and low draw to build positions should be seized, and it is considered whether the price spread trend will continue and the extent of continuation. MACD index is used to assist arbitrage, which makes the returns more stable than arbitrage of buying and selling different commodities at the same time.
References