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The Impact of U.S. Monetary Policy on Metal Futures Prices: An Arch Model Analysis

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Abstract: The article empirically examines the impact of U.S. monetary policy on futures prices of non-ferrous metals (including copper, alum, zinc, lead, tin, nickel, and overall non-ferrous metal price index), using the data since the 1980s. The regression analysis with the arch model indicates that the rise of federal funds rates has some extent explaining power on the decrease of metal futures prices, as shown by the significant negative relationship between them. Intuitively, an increase in interest rates reduces currency liquidity and suppresses the demand for commodities such as non-ferrous metals, thus the decrease of their prices. Besides, this research also identifies a significant correlation between futures prices and M2, with a positive correlation between the means of their variables and a negative correlation between the variances of the variables. The metal spot price reasonably predicts its corresponding future prices, as those two prices are found significantly positively correlated with coefficients around 0.9-1.1.

Keywords: federal fund rate, M2, metal future prices, spot prices, arch model

1. Introduction

Non-Ferrous metals are essential materials for the development of the national economy. Aviation, aerospace, automotive, mechanical, electrical, communication, construction, and household appliances all rely on non-ferrous metal materials for their production. Therefore, the price of non-ferrous metals should be investigated and considered appropriate for the manufacturing and financial market.

Non-ferrous metals are alloys or metals that do not contain any noticeable amounts of iron. Their main components are aluminum, copper, lead, nickel, tin, titanium, zinc, and copper alloys like brass and bronze. Other precious non-ferrous metals are gold, silver, etc. Non-ferrous metals are often more expensive than steel with unique attributes, including lighter weights, conductivity, corrosion resistance, and non-magnetic properties that can be used for a wide range of commercial, industrial, and residential applications. Now, non-ferrous metals are not only circulating in international trade but also entering the futures market for investment. The world's non-ferrous metals futures trading is concentrated on the London Metal Exchange (LME), the New York Mercantile Exchange, and the Tokyo Industrial Products Exchange. In particular, the trading price of the London Metal Exchange futures contract is recognized worldwide as the pricing standard for non-ferrous metals trading. Therefore, the analysis in this paper focuses on six common non-ferrous metals, copper, aluminum, zinc, lead, tin, and nickel. All metal data are obtained from the London Futures Exchange.

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Most scholars have been studying the volatility of non-ferrous metals as a kind of commodity that impacts the global economy. Slade summarizes two main price-setting bodies: the North American producer pricing system and the London Metal Exchange pricing system [1]. Producer prices are fixed by the main North American companies in the sector, while exchange prices are set in competitive auctions in LME. Non-Ferrous metals are now mainly valued in U. S. dollars in the futures market. Watkins and McAleer were among the first to examine the pricing mechanism of forward markets by means of daily LME prices between 1 February 1986 and 30 September 1998 [2]. He has developed a framework for estimating long-term pricing models of LME metals futures by means of the risk premium and cost-of-carry theory. The approach was undertaken to accommodate the common time series properties of financial data, particularly the presence of stochastic trends in price levels.

In terms of price forecasts, Liu et al. point out that the forecasting of non-ferrous metals price methods can be divided into two categories, the single model method and the hybrid model approach [3]. The ARIMA single model, however, is more effective in estimating spot prices than in the future for non-ferrous metals. On the other hand, Zhu et al. used a hybrid approach, LHAR-CJ-G model, to predict the volatility of non-ferrous futures (such as Nickel and Aluminum futures) on the Shanghai Futures Exchange, and enhanced model explanation ability [4]. In recent years, machine learning has been widely used in price forecasting.

Another important research stream in this area is to detect the factors that can influence non-ferrous metals prices. It is possible to sum up all the factors, supply and demand, market expectations, and so on. Slade analyses five principal determinants of price volatility in the metal market: horizontal market structure, marketing approach, supply, demand, and time-span factor [1]. McMillan and Speight have shown that when non-ferrous commodities are more financed, they tend to have a greater impact on prices [5]. The former reason is of a short-term nature and concerns the effect of new information on the market as well as hedging or speculation. The second is a long-run effect resulting from fluctuations in the commodity market's reserves.

The non-ferrous metals market may also be influenced by other commodities, such as petroleum, clean energy, and rare metals. Mensi et al. show significantly lower tail dependence and upper tail independence between oil and non-ferrous metals markets [6]. Yahya et al. analyze the cross-quantile dependence and causality between non-ferrous metals and renewable energy indices by employing data from November 2003 to May 2019 [7]. Al-Yahyaee et al.look at the interaction of gold, silver, and non-ferrous metals (aluminum, copper, lead, and zinc) [8].

To summarise, first of all, we have discussed the pricing schemes and the models used to predict the prices of non-ferrous metals. Their pricing systems are producer pricing and exchange pricing. Nowadays, exchange rate pricing has been widely applied. Price prediction models are single-model methods ARIMA and mixed model LHAR-CJ-G. Then, the influencing factors of non-ferrous metal prices are discussed. But one factor that seems to me to be undervalued is the US monetary policy because non-ferrous metals are valued in dollars. This study looks at the impact of US monetary policy on the price of non-ferrous metals in order to offset this difference.

In fact, there have been three massive dollar rate hikes in history that have had a significant impact on the price of copper. In June 1999 the Federal Reserve began to gradually tighten monetary policy due to the financial crisis in Southeast Asia overlaid with Russian debt default and other factors, and raised interest rates six times in 11 months, with a cumulative range of 175 basis points. Copper prices fell before the start of the rate hike and rose overall during the hike cycle. In June 2004, with the bursting of the technology stock bubble and the US economy falling back into recession, the Fed announced 17 rate hikes, with a cumulative increase of 425 basis points. Copper prices experienced a round of declines in the quarter before the rate hike. From 2007 to 2008, the U.S. subprime mortgage crisis, the economy was again severely depressed, the Fed cut interest rates 11 times, the federal funds

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rate fell to near 0, copper prices also entered a period of decline before the interest rate hike, a short adjustment up. Nowadays, Covid-19, the Russia-Ukraine conflict, and other issues bring great uncertainty to the U.S. monetary policy, and always influence market changes. These are the relevance of this research.

Some papers related to U.S. monetary policy can provide support to this research. Hammoudeh et al. found that positive interest rate shock results in permanent decreases in metals and energy prices [9]. Gospodinov and Jamali examine the impact of monetary policy uncertainty on commodity prices to demonstrate that the uncertainty linked to adverse monetary policy shocks (that is, a higher-than-expected decline in the target interest rate) will result in a decline in future prices of certain energy and metals. All these points of view have been verified in the article [10].

The paper is structured as follows. Section 2 describes the metal price data characteristics and the ARCH method. Section 3 analyzes the model results, with a strong correlation between nonferrous metals and monetary policy. Section 4 makes a summary.

2. Data and Methodology

2.1. Data

The non-ferrous metals market sample includes monthly averages of 3-month contract futures closing prices, monthly averages of spot settlement prices, and the LME base metals index for six common metals (copper, aluminum, zinc, lead, tin, and nickel) on the London Futures Exchange. Monetary policy data includes M2 and Federal Funds Effective Rate for the U.S. The U.S. monetary policy data is selected because the U.S. dollar is the currency in which commodities are priced. The London Futures Exchange is also selected because it is the world's largest non-ferrous metals exchange and the exchange's prices and inventories have a significant impact on the production and sale of non-ferrous metals worldwide.

The LME Base Metal Index is designed to provide participants with a simple way to obtain prices for the six major non-ferrous metals on the LME. copper at 42.8%, aluminum at 31.2%, lead at 8.2%, nickel at 2%, tin at 1% and zinc at 14.8%. It started in 2003 and has 269 samples so far. The six metal futures price samples all started earlier than it, basically between 1986 and 1989. The earliest is copper on April 30, 1986, and the latest is on June 30, 1989. The spot price samples are all recorded later than the futures, with most periods beginning on December 31, 2003, and ending on August 31, 2022, except for zinc, which begins in 1989. For the monetary policy sample, both are larger than the non-ferrous price sample, M2 from 1959 to 2022, and the Federal Funds Effective Rate for the U.S. from 1954 to the present. The details can be observed in Table 1.

Table 1: Data and samples (monthly).

Market	Observations	Start date	Sample size
Copper Futures prices	1986-2022	30-Apr-86	437
Alum Futures prices	1987-2022	30-Jun-86	423
Zinc Futures prices	1989-2022	31-Jan-89	404
Lead Futures prices	1987-2022	31-Jan-87	428
Tin Futures prices	1989-2022	30-Jun-89	399
Nickel Futures prices	1987-2022	31-Jan-87	428
Copper Spot prices	2003-2022	31-Dec-03	225
Alum Spot prices	2003-2022	31-Dec-03	225
Zinc Spot prices	1989-2022	31-Jan-89	404
Lead Spot prices	2003-2022	31-Dec-03	225
Tin Spot prices	2003-2022	31-Dec-03	225
Nickel Spot prices	2003-2022	31-Dec-03	225

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Table 1: (continued).

M2	1959-2022	01-Jan-59	764
LME Base Metal Index	2005-2022	01-May-05	269
FederalFundsEffective Rate	1954-2022	01-Jul-54	891

Non-ferrous metal prices are the most important sample studied in this thesis. In table 2 their quantitative characteristics (mean, SD, variance, CV, maximum value, minimum value) are calculated. We can observe that tin and nickel prices are relatively high and copper, aluminum, zinc, and lead prices follow. This is in line with the market perception, related to the production and specific use of metal mines. In terms of price increases, copper, tin, and nickel prices are variable, while aluminum, zinc, and lead are stable. Because copper, aluminum, and zinc have a wide range of applications and are base metals with large market volumes, price changes are relatively small. Copper, as the most traded metal, is, therefore, more volatile than the other two. Next, tin and nickel futures position volume is relatively small, so price fluctuations are more violent compared to base metals like copper and aluminum, often a small amount of money can drive the plate market, so speculative attributes are relatively strong.

Table 2: Data Features.

	Copper	Alum	Zinc	Lead	Tin	Nickel
Mean	4341.92	1838.07	1774.67	1285.82	12901.66	12771.26
SD	2600.80	459.95	811.45	784.55	8449.69	7429.87
CV	0.60	0.25	0.46	0.61	0.66	0.58
Max	10247.48	3517.67	4323.83	3660.66	43779	48888.10
Min	1317.26	1060.98	767.6	389.34	3728.25	2381.45

In summary, non-ferrous futures prices are the dependent variables, and gross monetary value M2, the federal funds rate, and non-ferrous spot prices are the independent variables. As shown in figure 1, the data was taken log value. All six metals had a substantial price increase between 2000 and 2010. The prices of aluminum and nickel have a bell-shaped distribution and the other four metals have a U-shaped distribution. However, all of them approximate a positive-terminus distribution. This is consistent with the change in the metal index in Figure 2. The characteristics of the U.S. monetary policy data are visualized in Figures 3 and 4. Federal interest rates have fluctuated down from 1980 to 2010, but have been up and down in recent years with no clear trend. Monetary issuance is in a constant state of increase.

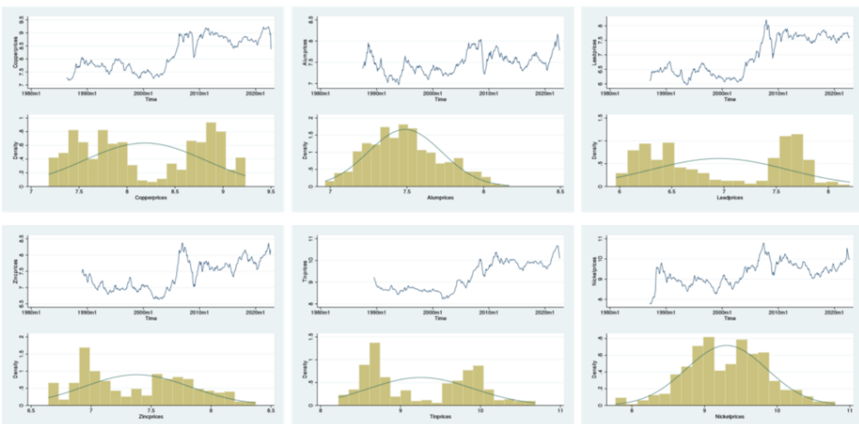

Figure 1. Metal Futures Price.

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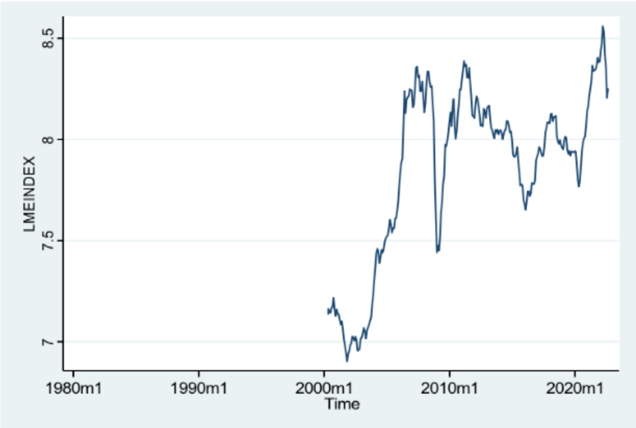

Figure 2: LME Index.

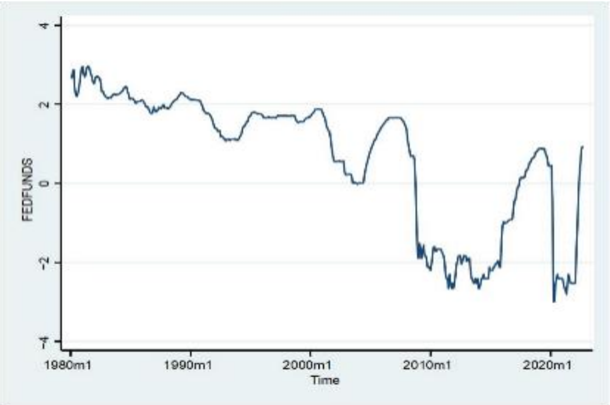

Figure 3: Table 3. FEDFUNDS.

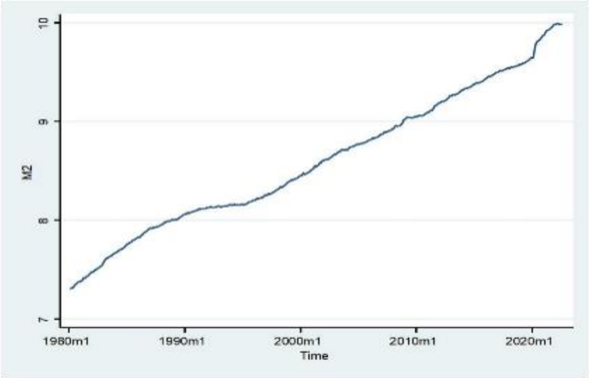

Figure 4: M2 for USA.

2.2. Methodology

ARCH (autoregressive conditional heteroscedastic) model for the variance of a time series. ARCH models are used to describe variable and potentially variable deviations. While an ARCH model can potentially be used to describe incremental dispersion over time, it is mostly applied when there can be brief periods of high variability. (Incremental dispersion associated with progressively rising average may be best dealt with by transformation of a variable.)

Suppose that we are modeling the variance of a series y_t. The ARCH (1) model for the variance of model y_t is that conditional on y_{t-1}, the variance at time is

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$$Var(y_t|y_{t-1}) = \sigma_t^2 = a_0 + a_1 y_{t-1}^2 \tag{1}$$

We impose the constraints a ⩾ 0 and a ⩾ 0 to avoid negative variance.

If we assume that the series has mean = 0 (this can always be done by centering), the ARCH model could be written as

$$y_t = \sigma_t \epsilon_t \tag{2}$$

with $\sigma_t = \sqrt{a_0 + a_1 y_{t-1}^2}$ and $\epsilon_t \overset{iid}{\sim} (\mu = 0, \sigma^2 = 1)$

For inference (and maximum likelihood estimation) we would also assume that the ϵt are normally distributed. Two potentially useful properties of the useful theoretical property of the ARCH (1) model as written in equation (2) above are the following:

- y_t^2 has the AR (1) model $\boldsymbol{y_t^2 = a_0 + a_1 y_{t-1}^2 + error}$;
- This model will be causal, meaning it can be converted to a legitimate infinite order MA only when white noise when $a_1^2 < 1/3y_t$ is white noise when $0 \leqslant a_1 \leqslant 1$.

The variance of a random variable measures its variation around its mean. The covariance between two random variables will show that their variations are around their respective means.

The conditional variance of a random variable X is a measure of how much variation is left behind after some of it is 'explained away' via X's association with other random variables Y, X, W, etc. It is expressed in notation form as Var (X-Y, X, W) and read off as the Variance of X conditioned upon Y, Z, and W. The formula for the unconditional (total) variance:

$$\mathrm{Var(X)} = \frac{\sum_{i=1}^{n}(x_i - \Sigma(X))^2}{n-1} \tag{3}$$

In the above formula, E(X) is the "unconditional" expectation (mean) of X.

Conditional covariance that covariance between two random variables X and Z is a measure of how correlated the variations in X and Z are with each other. Its formula is as follows:

$$\mathrm{Cov(X, Z)} = \frac{\sum_{i=1}^{n}(x_i - \Sigma(X))(z_i - \Sigma(Z))}{n-1} \tag{4}$$

In this formula, E(X) and E(Z) are the unconditional means (a.k.a. unconditional expectations) of X and Z.

3. Empirical Results

The general idea is to take the non-ferrous metal price as the dependent variable, select the U.S. Federal fund rate, U.S. gross monetary value M2, and metal spot price to form different combinations as independent variables, and use the arch model to study the regression relationship. On this basis, the mean and variance of the above variables are found, and the correlation is verified by applying Conditional variance and using the arch model again.

First of all, at the beginning of the selection of independent variables, we have tried to conduct correlation analysis using U.S. federal fund rate, U.S. monetary aggregates, spot price, futures trading volume, metal inventory, and metal supply and demand balance values. Since different variable selections can lead to a diversity of results, after making different combinations of attempts, only the top three (U.S. Federal fund rate, U.S. M2, Spot price) were taken as independent variables, and the results of the resulting study have some regularity.

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Table 3: Results of the three variables arch model.

Variables	LME Index	Copper	Alum	Zinc	Lead	Tin	Nickel
Federal fund rate	-0.0617**[1]	-0.0124**	-0.0174**	-0.0044**	-0.0040**	-0.0013**	-[2]
M2	0.5400**	-	-0.0105**	-0.085**	0.0070**	-0.0032**	-0.0075**
Spot price	-	0.9924**	0.9851**	1.0044**	1.0226**	0.9934**	0.9933**
Arch. L1	1.1015**	1.0838**	0.6274**	1.7686**	0.9235**	1.6089**	1.6675**

First, according to Table 3, it can be found that nickel futures price and federal fund rate, copper futures price, and M2 do not have much correlation under the three independent variables when the p-values are all greater than 5%. Therefore, the model is debugged and the arch model is applied to the independent and dependent variables separately, and the results are found to be correlated. For example, when the independent variables are the federal funds rate, M2, and the spot price, the futures price of nickel is not correlated with the federal funds rate. However, a p-value of less than 5% is relevant when the federal funds rate and the futures price of nickel are calculated individually. The lack of correlation in the trivariate case may be influenced by the interrelationship between the independent variables. Second, there is a strong and negative correlation between the LME Index and the six metal futures prices and the federal funds rate - when the federal funds rate rises, metal futures prices fall. In the traditional framework, interest rate increases reduce liquidity, and commodities such as nonferrous metals should be depressed. Third, for M2, the LME Index and lead are positively correlated, while aluminum, zinc, tin, and nickel are negatively correlated. The reason for this may be that on the one hand, there is a time lag in the transmission of interest rate hikes, and the Fed will release interest rate hike expectations several times before the hike, making market prices digest the negative factors in advance and amortize the impact of the hike on the market; on the other hand, interest rate hikes are not necessarily a decisive factor in the rise and fall of non-ferrous metal prices, and the strength of their supply and demand relationships may dissipate the impact of interest rate hikes. In addition, each metal futures price and spot price are positively correlated, and the coefficient is stable around 1.0.

Table 4: Results of the Federal fund rate variable arch model.

Variables	LME Index	Copper	Alum	Zinc	Lead	Tin	Nickel
Federal fund rate	-0.0914**	-0.0012**	-0.0018**	-0.0014**	-0.0047**	-0.0012**	0.0008**
Spot price	-	0.9928**	0.9871**	1.0010**	1.0263**	0.9923**	0.9977**
Arch. L1	1.0820**	1.0838**	0.5319**	2.6188**	1.0522**	1.5495**	1.9520**

Table 5: Results of the mean variables arch model.

Variables	LME Index	Copper	Alum	Zinc	Lead	Tin	Nickel
M2	0.7256**	-	-.0090**	-0.0032**	0.0186**	-0.0028**	-0.0078**
Spot price	-	0.9929**	0.9779**	0.9989**	1.0183**	0.9962**	0.9936**
Arch. L1	1.0393**	0.7391**	0.8052**	2.0025**	1.0838**	1.5338**	1.7500**

Next, since considering different variable choices and relationships between variables can affect the final results. We will separate the federal funds rate and M2 in monetary policy to test the arch model for metal futures prices separately. The correlations and the positive and negative directions of the coefficients in Table 4 are generally consistent with those in Table 3. Copper and M2, tin, and

[1] **represents significance level at 5%

[2] -represents no correlation or lack of data

the federal funds rate are uncorrelated under the three variables in Table 3, and all are correlated in Table 4 after reducing the variables. Therefore, copper is strongly correlated with M2, tin and the federal funds rate without the influence of spot prices, with coefficients of 0.7845 and -0.1667 and the same general trend.

Finally, the mean and variance of each variable were calculated and an arch model between Conditional Variance and Conditional Covariance was developed to verify the correlation effect. Figure 5 shows the trend of the mean and variance of the six metals. The mean is basically rising in variation and the maximum value of the variance mostly occurs around 2010 indicating that the metal futures prices were more volatile at that time and correlated with the financial crisis in 2008. To ensure the completeness of the test, we also try to apply different combinations of variables to perform the arch model test one by one. Since the mean or variance of M2, the federal funds rate, and spot prices are used simultaneously as dependent variables, the results are asymmetric and no pattern can be identified. If the combination of the two variables still does not yield results, one independent variable and one dependent variable are used for debugging as in the above steps. Among them, the data on aluminum has an extremely special characteristic in that its variance is not correlated. Probably because aluminum has a wide range of applications and strong consumption attributes, the consumption growth rate is closely related to the macroeconomy and is stronger than other base metals, both in terms of growth rate and application expansion. For average, when the federal funds rate rises, futures prices fall; when M2 rises, futures prices rise. This is in general agreement with the table above. For the variance, copper and tin are the ones whose prices change less the more the federal funds rate changes; the opposite is true for zinc-lead-nickel. All metal prices change to a lesser extent with larger changes in M2. Commodity futures price changes are not entirely influenced by financial markets but are still closely related to supply and demand.

Figure 5: Mean and Variance.

Table 6: Results of the mean variables arch model.

Variables	LME Index	Copper	Alum	Zinc	Lead	Tin	Nickel
Federal fund rate	-0.0625**	-0.0435**	-	0.0167**	-0.0849**	-0.0836**	0.0613**
M2	0.5355**	0.6766**	0.1472**	0.6578**	0.7983**	0.8259**	0.3432**
Arch. L1	1.1015**	1.0645**	1.0202**	1.0551**	1.0514**	1.0245**	1.6675**

Table 7: Results of the variance variables arch model.

Variables	Copper	Alum	Zinc	Lead	Tin	Nickel
Federal fund rate	-0.0154**	-	0.0006**	0.0034**	-0.0041**	0.0015**
M2	-68.2735**	-	-1.9459**	-24.0481**	-15.9305**	-6.7679**
Arch. L1	2.6007**	0.6274**	4.8719**	1.8944**	1.6259**	13.0364**

Overall, our empirical test has the following findings (1) a strong correlation between metal futures prices and the federal funds rate with a negative coefficient - when the federal funds rate rises, metal futures prices fall; (2) a strong correlation between metal futures prices and M2 as well. If we calculate the correlation coefficients of the two variables directly, there is no pattern of positive or negative coefficients; if we calculate the correlation of the mean of the two variables, the mean of M2 rises and the mean of metal futures prices rises, and if we calculate the correlation of the variance of the two variables, all metal futures prices change to a lesser extent with the greater change in M2. (3) Each metal futures price and spot price are positively correlated and the coefficient is stable around 1.00. After reviewing the literature and observing the market, we believe that the reasons for the above phenomenon are (1) the interest rate increase will reduce the liquidity of the currency, the dollar will appreciate, and the non-ferrous metals, which are denominated in dollars, will fall, which is negative for the non-ferrous metals. (2) From the analysis of the financial product market, the product price is proportional to the sum of future cash flow and inversely proportional to the interest rate. If the interest rate rises, the price goes down. (3) Interest rate increases lead to increased real and opportunity costs, people are less willing to invest, fewer buyers, and prices fall. (4) Commodity futures price movements are not entirely influenced by financial markets but are also related to metal characteristics and supply and demand.

4. Conclusion

This paper uses arch model variables to estimate the impact of U.S. monetary policy data on nonferrous metals futures prices. Non-ferrous metals, as commodities priced in U.S. dollars, have both commodity and financial attributes. On the one hand, they are heavily influenced by supply and demand in terms of capacity production and utilization pathways. On the other hand, such prices are also affected by inflation in the U.S. and the Federal Reserve's interest rate hikes and tapering policies.

The Arch model first identifies a strong and negative correlation between the LME Index, six metals futures prices, and the federal funds rate. When the federal funds rate rises, metals futures prices fall. This is because the shock interest rate will reduce monetary liquidity, and the dollar will appreciate. The non-ferrous metals, which are denominated in dollars, will fall. From the analysis of the financial product market, the price of a product is proportional to the sum of future cash flows and inversely proportional to interest rates. If interest rates rise, prices go down; interest rate increases lead to an increase in real and opportunity costs, people are less willing to invest, buyers decrease, and prices fall.

Secondly, there is an extremely strong correlation between the LME Index and six metals futures prices and total U.S. money issuance M2, but the coefficients have different signs. The LME Index and lead are positively correlated, while aluminum, zinc, tin, and nickel negatively correlate. However, the mean of M2 rises while the mean of the six metals (including copper, alum, zinc, lead, tin, and nickel) futures prices rise. The six metals futures prices all change to a lesser extent with the more significant movement of M2. This is because of the lag in monetary policy transmission. In other words, the Federal Reserve in printing money before the release of printing expectations so that market prices digest the negative factors in advance, amortizing the impact of interest rate hikes on the market. On the other hand, the total amount of money is not necessarily a decisive factor in the rise and fall of non-ferrous metal prices, the strength of their supply and demand relations may dissipate the impact.

Thirdly, each metal futures price and spot price are positively correlated, and the coefficients hover around 0.9-1.1. On this basis, Conditional Variance and Conditional Covariance are used to find the variance and mean of the variables. Then the arch model is used to verify the above conjecture.

The advantage of this paper is that the data is comprehensive, and the model fits well, which can provide a reference for the forecast of non-ferrous metal price trends in the future market. However, the model is single, the number of variables considered is small, and the dollar index and dollar exchange rate can be added to the specific case analysis.

References

[1] *Slade, M. E. (1989). The two pricing systems for non-ferrous metals. Resources Policy 15(3), 209–220.*

[2] *Watkins, C. and M. McAleer (2006). Pricing of non-ferrous metals futures on the london metal exchange. Applied Financial Economics 16(12), 853–880.*

[3] *Liu, Y., C. Yang, K. Huang, and W. Gui (2020). Non-ferrous metals price forecasting based on variational mode decomposition and lstm network. Knowledge-Based Systems 188, 105006.*

[4] *Zhu, X.-h., H.-w. Zhang, and M.-r. Zhong (2017). Volatility forecasting in chinese nonferrous metals futures market. Transactions of Nonferrous Metals Society of China 27(5), 1206–1214.*

[5] *McMillan, D. G. and A. E. Speight (2001). Non-ferrous metals price volatility: a component analysis. Resources Policy 27(3), 199–207.*

[6] *Mensi, W., M. U. Rehman, and X. V. Vo (2021). Risk spillovers and diversification between oil and non-ferrous metals during bear and bull market states. Resources Policy 72, 102132.*

[7] *Yahya, M., S. Ghosh, K. Kanjilal, A. Dutta, and G. S. Uddin (2020). Evaluation of crossquantile dependence and causality between non-ferrous metals and clean energy indexes. Energy 202, 117777.*

[8] *Al-Yahyaee, K. H., M. U. Rehman, I. M. W. Al-Jarrah, W. Mensi, and X. V. Vo (2020). Co-movements and spillovers between prices of precious metals and non-ferrous metals: A multiscale analysis. Resources Policy 67, 101680.*

[9] *Hammoudeh, S., D. K. Nguyen, and R. M. Sousa (2015). Us monetary policy and sectoral commodity prices. Journal of International Money and Finance 57, 61–85.*

[10] *Gospodinov, N. and I. Jamali (2015). The response of stock market volatility to futures-based measures of monetary policy shocks. International Review of Economics & Finance 37, 42–54.*