Coupling Analysis of Commodity Supply Concepts and Price Volatility Spillover in China 2030 - Copper as an Example

Haoxuan Li
College of Economic and Management, Changchun University of Science and Technology, Changchun, 130012 Jilin, China
1376880822@qq.com

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Abstract: The study forecasts China's 2030 copper consumption and estimates various copper supply indicators by regression analysis and normal lifetime distribution to construct supply scenarios under different conditions. The BEKK-GARCH model is employed to investigate the volatility spillover effects between futures and spot markets, due to the intricate global economic climate of recent years, which has caused commodity prices to become excessively volatile. A coupling analysis is conducted to conclude that China should choose a trend reduction strategy for its future import planning. Meanwhile, the volatility of futures and spot markets is asymmetric and aggregated, so attention should be paid to the price volatility anomalies brought about by supply changes.

1. Introduction

In 2020, China proposed a new development model based on a “double-loop” model, in which the domestic loop is the main axis and domestic and international loops support each other. With the impact of the New Crown Pneumonia epidemic on the global commodity market, the global mineral resource supply chain has undergone dramatic changes. The industrialization process of a country is closely related to the fluctuation of supply and demand of mineral resources. The prediction and study of these changes have both academic and practical significance. Also the role of enhancing copper price volatility forecasting is undeniable, as volatility is an important indicator of market risk.

Field validation using data for China from 2000-2022 is used to forecast the period 2023-2030. In addition to Chapter 1, the remaining chapters of the paper are organized as follows: Chapter 2 introduces the fundamentals of the empirical model. Chapter 3 performs the example measurement. Supply and demand evaluation indicators are constructed based on the projected copper consumption function, and three supply scenarios are assumed to forecast future import and inventory flows. A BEKK-GARCH model is also used to quantify the volatility spillover between futures and spot prices. Chapter 4 provides a coupled analysis of the relevant findings and makes recommendations. Chapter 5 presents the conclusions obtained from the study.

2. Methodology

2.1 Domestic Copper Consumption

Regression analysis has been employed in a number of studies to forecast the future utilization of certain metals[1]. The general approach is to perform a regression analysis with copper metal consumption using macro variables measuring the level of socioeconomic development as independent variables. Equation (1) furnishes the form of the regression equation.

$$Y(T)=\alpha_o+\sum_{n=1}^{n}\alpha_n X_n(T)+\varepsilon(T) \qquad (1)$$

Where $Y(T)$ is the copper consumption at time T, n is the number of explanatory variables, $X_n(T)$

is the explanatory variable at time T, α_0 is the parameter of the regression model, and $\varepsilon(T)$ is the residual of the regression model. In this study, GDP per capita, urbanization rate, and population are used as explanatory variables for the regression analysis of domestic copper consumption in China from 2000 to 2022[2].

2.2 Generate Copper Scrap

Four main copper lifetime distributions exist generally: i) uniform, ii) normal, iii) Weibull, and iv) beta[3].Compared to other life expectancy distributions, the normal distribution has the advantage of being easier to calculate and more flexible in its application[4]. Therefore, in this paper we choose the normal distribution to quantify the life expectancy distribution of copper-containing products for different end-use categories.

The probability density function of the $f(t)$ matrix for the copper-containing product group and the distribution function of the $P(t)$, whose sum is derived from the $S_{T,scarp\ generation}$ for copper scrap produced in year T, are shown below.

$$f(i) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(i-\mu)^2}{2\sigma^2}} \tag{2}$$

$$P(i) = \frac{1}{\sigma\sqrt{2\pi}} \int_i^{i+1} e^{-\frac{(i-\mu)^2}{2\sigma^2}} dx, a \le i < b \tag{3}$$

$$S_{T,\text{scarp generation}} = \sum_{i=a}^{b-1} Y_{T-i} * P(i) \tag{4}$$

2.3 Evaluation Criteria

Most of the copper circulating in China relies heavily on one-way "internal" consumption and "external" supply [5]. This study introduces an evaluation criterion, R, to illustrate the correlation between domestic consumption and supply. R is the ratio of the copper consumed domestically in a given year to the total supply entering the country. The mathematical expression of R is given in Equation (5).

$$R_T = \frac{M_{T,\text{consumption}}}{M_{T,\text{total}}} \tag{5}$$

Where $M_{T,consumption}$ indicates the total domestic consumption of copper in year T; $M_{T,total}$ indicates the total supply flowing into the country in year T. $M_{T,total}$ Specifically includes and $S_{T,recycled}$ the amount of copper recycled domestically in year T, $S_{T,import\ or\ output}$ the amount of copper imported and exported in year T, $S_{T,in-use\ stock}$ the amount of copper used from previous stocks during year T, and $S_{T,primary}$ the amount of copper produced domestically in year T. The specific form is shown in equation (6) below. $S_{T,recycled}$ It can also be expressed as the product of the degree of conversion of copper scrap in k and the value of copper scrap generated in year T, as shown in equation (7).

$$M_{T,total} = S_{T,recycled} \pm S_{T,import\ or\ output} \pm S_{T,in-use\ stock} + S_{T,\text{primary}} \tag{6}$$

$$S_{T,recycled} = k * S_{T,scarp\ generation} \tag{7}$$

Supply and demand evaluation criteria R_T theoretically the closer to one the more reasonable, when R_T is greater than one the supply is not enough to meet the demand, when R_T is less than one is the excess supply over the demand.

2.4 Fluctuation Spillover Model

A multivariate BEKK-GARCH model is employed in this paper to observe the volatility spillover effects of spot and futures market prices over time. The commonly used GARCH form is:

$$P_t = x_t\theta + \varepsilon_t, \varepsilon_t \mid \Im \sim N(0, h_t) \quad (8)$$

$$h_t = a_0 + a_1\varepsilon_{t-1}^2 + \beta_1 h_{t-1} \quad (9)$$

In this model, θ is the coefficient vector of this equation, the explanatory variables are represented by x_t, and since it's a normal distribution, the residual is represented by ε_t, and the conditional variance is represented by h_t. Since spot prices and futures prices of bulk resources are often different, multivariable GARCH model, namely vector GARCH model, is adopted for price volatility spillover between them, in which residual sequence of mean equation follows multivariate normal distribution [6]and is expressed by H_t conditional covariance matrix. In this paper, BEKK form is adopted to set up the variance equation:

$$H_t = W + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B \quad (10)$$

$$W = \begin{pmatrix} \omega_1 & 0 \\ \omega_2 & \omega_3 \end{pmatrix} \quad A = \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \quad B = \begin{pmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{pmatrix} \quad (11)$$

Where W is the constant coefficient matrix, A is the conditional coefficient matrix of the residual matrix, and B is the conditional coefficient matrix of the covariance matrix.Specifically, the multivariate BEKK-GARCH model is described as follows. The conditional mean equation and the conditional variance covariance matrix are shown below:

$$P_t = \begin{pmatrix} P_{1,t} \\ P_{2,t} \end{pmatrix} = \begin{pmatrix} C_1 \\ C_2 \end{pmatrix} + \begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix}\begin{pmatrix} R_{1,t-1} \\ R_{2,t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} \quad (12)$$

$$h_t = \begin{pmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{pmatrix} = \begin{pmatrix} \omega_1 & 0 \\ \omega_2 & \omega_3 \end{pmatrix}'\begin{pmatrix} \omega_1 & 0 \\ \omega_2 & \omega_3 \end{pmatrix} + \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix}'\begin{pmatrix} \varepsilon_{1,t-1} \\ \varepsilon_{2,t-1} \end{pmatrix}\begin{pmatrix} \varepsilon_{1,t-1} & \varepsilon_{2,t-1} \end{pmatrix}\begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix}$$
$$+ \begin{pmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{pmatrix}'\begin{pmatrix} h_{1,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{2,t-1} \end{pmatrix}\begin{pmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{pmatrix} \quad (13)$$

P_t represents the spot price at time t, which is a 2×1-dimensional vector series; ε_t represents the market shock at time t, which is also a 2×1-dimensional vector series of random errors. $h_{11,t}$ represents the conditional variance of the spot price, $h_{22,t}$ represents the conditional variance of the futures price, and $h_{12,t}$ represents the conditional covariance of the spot and futures prices.

Particularly, α_{11} and β_{11} depict the ARCH and GARCH fluctuation effects of the spot itself; β_{11} α_{22} and β_{22} depict the ARCH and GARCH volatility effects of the futures themselves; α_{12} and β_{12} depict the ARCH and GARCH volatility effects of the spot price on the futures price; α_{21} and β_{21} depict the ARCH and GARCH volatility effects of the futures market price on the spot market price; and depict the ARCH and GARCH volatility effects of the futures market price on the spot market price[7]. The ARCH and GARCH volatility effects of futures market prices on spot market prices.

This paper performs Wald tests on the matrix elements to assess the spillover effects between spot and futures. A total of three hypotheses are included:

IThe conditional variance of the futures market is solely affected by its prior values, and there is no spillover of volatility from the spot market to the futures market; this is the initial supposition: $H_0: a_{12} = b_{12} = 0$.

II No spillover of volatility from the futures market to the spot market is assumed, with no unidirectional effect: $H_0: a_{21} = b_{21} = 0$.

III Assuming no two-way volatility spillover between the two markets, the initial supposition is: $H_0: a_{12} = b_{12} = a_{21} = b_{21} = 0$.

2.5 Data Sources

Obtaining the National Bureau of Statistics of China's historical data on urbanization rate, total population and GDP, the Oriental Fortune Choice database provides Chinese copper consumption, and the iFinD provides global copper consumption and primary copper production. The sample data used in this paper for the price volatility spillover model are taken from CSMAR December 31, 2019 to December 31, 2022. The daily returns are calculated using log returns.

3. Empirical Analysis

3.1 Domestic Copper Consumption

The linear regression analysis model R-squared value of 0.982 implies that the urbanization rate, total population, and GDP can explain 98.2% of the variation in copper consumption in China.

According to the forecast data by Qunyi Liu et al [8], the total global demand for copper will reach 2,933,800 tons by 2030.The results of this study suggest that copper consumption in China will reach 1,694,700 tons approximately by 2030, with an average annual growth rate of 2.2%. Meanwhile, China's share of global copper consumption gradually stabilizes, slowly increasing to 57.7% by 2030.As shown in Figure 1.

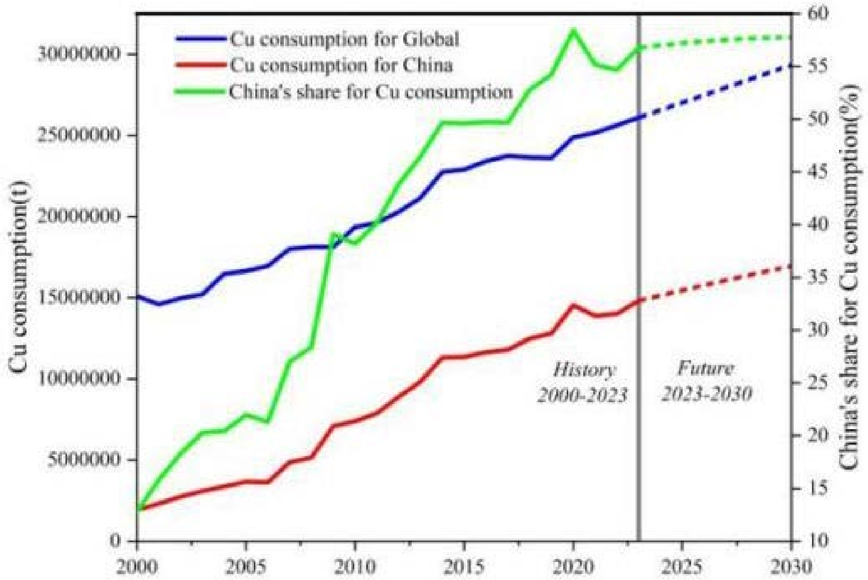

Fig.1 The Copper Consumption

3.2 Generate Copper Scrap

Probability density function of the normal distribution of copper product life cycle with the values of the parameters in the distribution function [9], the series of copper consumption in China was brought in to obtain the results of the generation of old copper scrap in China from 2000 to 2030 shown in Figure 2. The amount of old copper generated in 2000 was 289,000 tons of scrap, which gradually increased to about 2,478,000 tons in 2020, and it is expected that by 2030, copper scrap production will be 3,274,000 tons, almost equivalent to the copper consumption of 3,364,000 tons in 2004.

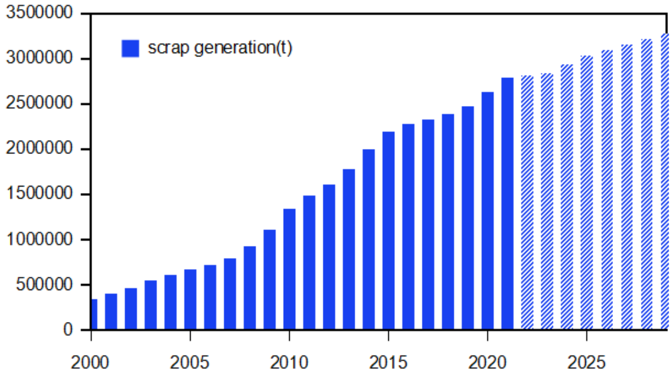

Fig.2 The Scarp Generation

3.3 Evaluation Indicators

Observing the historical data of domestic primary copper mines from 2000 to 2022, the overall cyclical increasing trend was observed, and the development cycle of copper mines was 8 years[10]. The trend curve was fitted by moving average and the future copper mining volume from 2023 to 2030 was predicted, as shown in Figure 3.

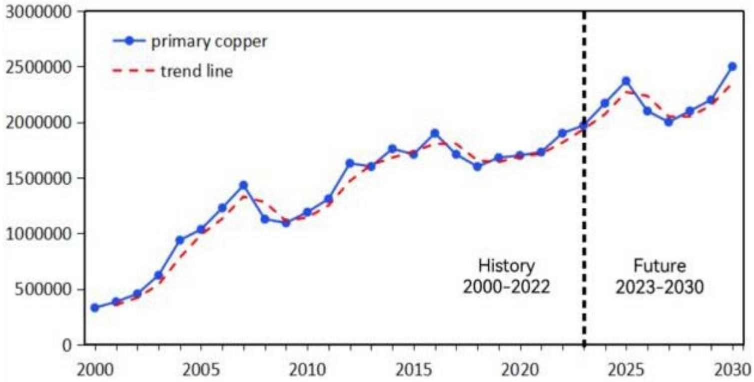

Fig.3 Domestic Primary Copper Production

Make $S_{T,import\ or\ output}$ and $S_{T,in-use\ stock}$ equal to zero. At this point, if we want to guarantee the theoretical best of copper supply and demand evaluation index, the sum of $S_{T,import\ or\ output}$ and $S_{T,in-use\ stock}$ should be equal to the difference between the total consumption of copper in China and the amount of domestic primary copper and recycled copper (hereinafter referred to as Balance). China is a net importer of copper[11]. So the specific value of $S_{T,in-use\ stock}$ can be obtained by subtracting Balance from China's copper imports from 2000-2022 under the assumption of the theoretical optimum of the evaluation index. $S_{T,in-use\ stock}$ is negative when the amount of stock outflows, and positive when it indicates stock inflows, as shown in Figure 4.

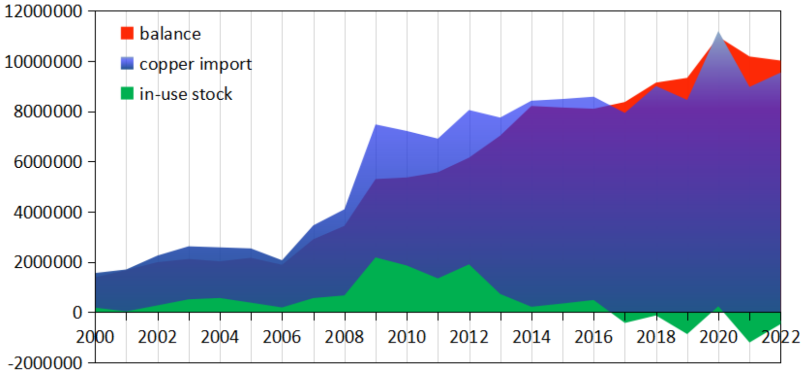

Fig.4 Copper Import and Stock Flow Mix

For the purpose of analysis and discussion, three scenarios are established in this study: normal business scenario (Scenario A), trend reduction scenario (Scenario B), and actual reduction scenario (Scenario C).

Scenario A: China is assumed to keep its current high copper import profile unchanged. Accordingly, in Scenario A, the growth trend in the value of imports from 2023 to 2030 is unchanged (slope of about 1.064 after linear fit).

Scenario B: It is assumed that China remains a net importer of copper, but the trend of increasing net copper imports is slightly lower than in Scenario A (slope after linear fit is about 1.032).

Scenario C: The setup of this scenario assumes that the net imports have been gradually weakening since 2023, when China's copper imports show a real decrease (the slope of the linear fit is about 0.968).

Figure 5 shows China's copper imports under different scenarios for 2000-2030, and Figure 6 shows the corresponding inventory flows in the future. Under scenario A, China's imports would continue to grow to 15.674 million tons and stocks would change from a net outflow to a net inflow in 2025.Under scenario B, China's imports would continue to grow to 12.276 million tons and copper stock flows would change from a net outflow to a net inflow in 2030.Under scenario C, China's imports would fall to 7.356 million tons, close to the 2013 imports.

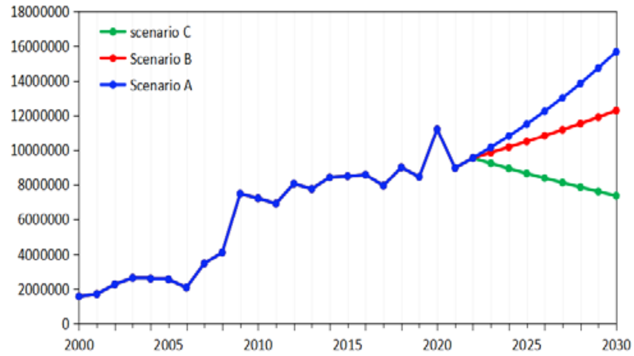

Fig.5 Copper Imports 2000-2030

Fig.6 Future Copper Inventory Flows

3.4 Fluctuation Spillover Model

In this paper, the BEKK-GARCH model is used for empirical analysis, which consists of conditional variance equation and conditional mean equation, and the dynamic relationship between first-order moment and second-order return moment is studied, respectively. The volatility test is performed in the form of the maximum likelihood ratio LR and Wald statistical tests: assuming that the residual vector of the condition follows a binary normal distribution[12], parameter estimation and fluctuation spillover effect test are completed using Winrats software, and the results are shown in Table 1 and Table 2.

Table 1 Model Parameter Estimation

Parameters	μ_1	μ_2	$c(1,1)$	$c(2,1)$	$c(2,2)$	$a(1,1)$	$a(1,2)$
Coefficients	0.898319	0.530230	-0.361336	-2.456863	0.019198	2.202319	0.115069
Significance level	***	***	*	***		***	**
T-statistics	15.14501	5.34245	-1.76559	-21.92768	0.00918	23.71341	2.44797
Parameters	$a(2,1)$	$a(2,2)$	$b(1,1)$	$b(1,2)$	$b(2,1)$	$b(2,2)$	
Coefficients	0.693806	0.212306	-0.193844	0.057881	-0.393784	-0.040478	
Significance level	***	***	***	**	***		
T-statistics	15.42225	4.05872	-5.81109	2.08423	-7.06875	-0.27838	

(***, **, and * denote 1%, 5%, and 10% significance levels, respectively; hereinafter)

Table 2 Testing for Volatility Spillover Effects

Null hypothesis	$H_0: a_{12} = b_{12} = 0$	$H_0: a_{21} = b_{21} = 0$	$H_0: a_{12} = b_{12} = a_{21} = b_{21} = 0$
LR	4.87559***	187.00967***	93.82146***
Wald	9.751173***	374.019337***	375.285848***

From the fluctuation of spot and futures market returns, only the diagonal elements $b(2,2)$ of matrices A and B in Table 1 are not significant, and the remaining elements are significant at the 1% confidence level. It shows that fluctuations in market returns are clearly influenced by their own past volatility and are persistent and clustered. The three original assumptions for the non-diagonal elements of A, B in Table 2 were rejected at the 1% confidence level. This suggests a significant two-way cross-market volatility spillover between the futures and spot markets[13].

As far as the volatility intensity of the spot market and the futures market is concerned, the estimated value of the parameter $a(2,1)$ is greater than $a(1,2)$, and the absolute value of the parameter $b(2,1)$ is greater than that of $b(1,2)$, indicating that the volatility spillover effect of the futures market on the spot market is greater than the volatility spillover effect of the spot market on the futures market, whether it is short-term or long-term, it shows asymmetry. This shows that the futures market has a higher priority than the spot market in terms of market liquidity and efficiency, and the price fluctuations of the futures market reflect the changes in market information relatively quickly, and play a leading role in information flow and risk transmission.

4. Recommendations

(1) When in the normal business scenario 2030 copper imports accounted for 93% of total consumption, if you want to get rid of foreign import dependence, you need to reduce the import growth ratio in a timely manner; in the actual reduction scenario China needs to face the pressure of inventory outflow all year round, which also makes China's reserves of copper will be reduced year by year; trend reduction scenario in the inventory in 2029 from a small amount of In the trend reduction scenario, the stockpile changes from a small amount of outflow to inflow in 2029, and copper imports account for 72% of total consumption in 2030 to achieve an effective reduction in external dependence. Therefore, it is recommended that the government choose a trend reduction strategy for future copper import planning.

(2) The volatility spillover effect between the copper spot and futures markets is two-way, asymmetric, and the futures market's effect on the spot market is more pronounced than that of the spot market on the futures market, implying that the futures market is the primary source of information. It is thus recommended that the government be attentive to the fluctuations in the futures market to direct production, consumption, and policy formation, and to abstain from short-sightedness due to anomalous prices in the immediate future[14].

(3) The mutual fluctuations of the two markets' yields at the same time are characterized by aggregation. It indicates that external shocks have a persistent effect on price fluctuations and that negative shocks of the same magnitude impact on volatility is greater than the positive shock, with

asymmetric price fluctuations. It is important to note whether the negative shocks from the trend decrease in supply can be hedged with the positive shocks from the actual increase when choosing the import strategy of trend decrease[15]. It is recommended that the government construct a special information system to warn of the risk of abnormal long-term price fluctuations.

5. Conclusions

The important impact of the mismatch between supply and demand for commodities exposes the drawbacks of China's sloppy growth model and the over-dependence of import-oriented industries on external markets. China's external dependence on copper is as high as 80%. And copper prices are prone to large fluctuations due to the influence of international markets. China's copper ore resources are scarce and the self-sufficiency rate is insufficient. This study assumes that the proportion of recycled copper remains unchanged, but based on China's huge historical copper consumption, a technological breakthrough to increase the proportion of recycled copper and generate sufficient supply is the key to break this situation. And the government should continue to take measures to promote effective domestic supply and accelerate industrial structure upgrading.

In the context of double-cycle politics, the impact of imbalances in basic domestic economic variables and market distortions will extend beyond national borders and the negative effects will be magnified. Especially when there is an imbalance between supply and demand, prices cannot reflect market changes of certain factors in a timely manner. This implies that future reforms should have a high starting point to correct the constraints and distortions in factor markets. in order to allocate resources efficiently in a dual domestic and international cycle. This will lead to a benign economic growth model, improve China's macroeconomic stability and enhance immunity to external shocks.

References

[1] Yue Qiang and Lu Zhongwu. Analysis on the Indexes of Copper Consumption in the Process of Industrialization for China and USA. Ecological Economy, 2007 (11): 28-32.

[2] Han See, Zhu Qing. Analysis of the impact of the new crown pneumonia outbreak on the mining market[J]. China Mining, 2020, 29(3): 1-5.

[3] Li S, Zhang T, Niu L, et al. Analysis of the development scenarios and greenhouse gas (GHG) emissions in China's aluminum industry till 2030[J]. Journal of Cleaner Production, 2021, 290: 125859.

[4] Li S, Wang Z, Yue Q, et al. Decomposition and decoupling analysis of aluminum in-use stocks in China[J]. Resources, Conservation and Recycling, 2022, 185: 106478.

[5] Xiuhua, Liu, Chunxue, Yin, Hao. Study on the factors influencing international price fluctuations of non-ferrous mineral products in the context of double-cycle--Copper and tin as examples[J]. Price Monthly, 2021, 9: 1-9.

[6] Fan, Lili, Liu, Lu. Analysis of carbon price yield volatility in China based on ARMA-GARCH model[J]. Economic circles,2020(05):25-32.

[7] Xie Q, Liu R, Qian T, et al. Linkages between the international crude oil market and the Chinese stock market: A BEKK-GARCH-AFD approach[J]. Energy Economics, 2021, 102: 105484.

[8] Liu Qunyi, Wang Anjian, Chen Qishen. Analysis of global copper demand trends to 2040[J]. China Mining, 2014, 8: 15-18.

[9] Qiu Y, Chen T, Cai J, et al. The Impact of Government Behavior on the Development of Cross-Border E-Commerce B2B Export Trading Enterprises Based on Evolutionary Game in the Context of “Dual-Cycle” Policy[J]. Journal of Theoretical and Applied Electronic Commerce Research, 2022, 17(4): 1741-1768.

[10] Glöser S, Soulier M, Tercero Espinoza L A. Dynamic analysis of global copper flows. Global

stocks, postconsumer material flows, recycling indicators, and uncertainty evaluation[J]. Environmental science & technology, 2013, 47(12): 6564-6572.

[11] Hao M, Tang L, Wang P, et al. Mapping China's copper cycle from 1950–2015: Role of international trade and secondary resources[J]. Resources, Conservation and Recycling, 2023, 188: 106700.

[12] Liu, Ying-Lin, Ju, Zhuo, Liu, Y-H. A study on the financialization of Chinese commodities based on DCC-GARCH[J]. International Business Research, 2017, 38(5): 75-83.

[13] Huo R, Ahmed A D. Relationships between Chinese stock market and its index futures market: Evaluating the impact of QFII scheme[J]. Research in International Business and Finance, 2018, 44: 135-152.

[14] Zhou Y, Wang X, Dong R K, et al. Natural resources commodity prices volatility: Evidence from COVID-19 for the US economy[J]. Resources Policy, 2022, 78: 102895.

[15] Lin J Y. Dual circulation and China's development[J]. Frontiers of Economics in China, 2021, 16(1): 30-34.