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China's Copper Demand Forecasting Based on System Dynamics Model

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Abstract: Copper demand for a country's copper industry has a greater pull effect. China's copper consumption in 2015 has accounted for 50% of the world. The scientific forecast of China's copper demands trend is also an important basis for analyzing its future environmental impact. This paper assumes that China's economy will be developing high, medium and low scenarios, and forecasts economic and social indicators such as total GDP, population and per capita GDP in China from 2016 to 2030. Then, predicted the demand of copper resources in China from 2016 to 2030 by the combination of system dynamics model, ARIMA model prediction and inverted U-type empirical model. The results show that: (1) in 2020, 2025 and 2030, China's refined copper demand will be 13 Mt, 15 Mt and 15.5 Mt. (2) China's copper demand growth slowed down significantly from 2016-2030. (3) 2025-2030, China's copper resource demand is stable, into the platform of demand growth, the highest peak value in 2027 will be 15.5 Mt. (4) 2030 years later, China's copper resource demand will enter a slow decline.

Keywords: copper resources; demand forecasting; system dynamics model; sustainability development

1. Introduction

Copper (Cu) is a widely distributed metal element, and the content of copper in the crust is about 0.01%. In some copper deposits, the content can reach 3%- 5% or even higher. Copper in nature is mostly in the form of compounds as copper mineral [1]. Copper is a second largest nonferrous metal used in aluminum, with excellent ductility, conductivity, thermal conductivity, and corrosion resistance. Mainly used for construction, transportation, machinery manufacturing, electronic appliances, home appliances and other five large areas [2].

China's reform and opening up more than 30 years of rapid growth, and now economic development has entered a new stage of structural transformation. China's economic development has been driven by investment-driven and export-oriented, turning to emphasis on innovation, structural adjustment, expanding domestic demand for endogenous growth. New urbanization, industry and consumption upgrades, investment in the people's livelihood infrastructure will inject new impetus into the future economic development [3]. What are the impact of the development of copper in the various sectors of the national economy in the next 10 to 15 years? Is worthy of study.

On the demand for copper, there have been many research results. For example, the relationship between copper consumption and GDP [4], copper demand law [5], future global copper demand [6-7], future demand for copper in China [8] and other aspects are analyzed. There has received some valuable research results, such as: future demand of copper driven by population and per capital incomes reducing concerns about supply [9]. The energy required to produce copper is expected to constitute between 1.0% and 2.4% of the total energy demand by 2050 [10]. China's Total Copper Consumption May Enter Stagnation Stage [11]. Behind, China's lower demand for copper including the Chinese government's efforts to make its economy a

domestic consumption-driven one and the role played by China's middle class in the slowing demand [12].

The research methods of supply and demand forecast of mineral resources are different that because of the research point of view, different ideas, methods between domestic and foreign scholars. There are two main approaches: Trend Extrapolation and Scenario Analysis. The essence of the Trend Extrapolation is that the researcher explores its development laws and trends through the study of the historical development of the research object, thus speculating on the possible state of the future. It includes time series analysis method, elastic coefficient method, multi-objective linear programming method, input-output method, RBF (Radial Basis Function) neural network model, artificial intelligence simulation model, logistic model, combined forecasting model, LEAP (Long-range Energy Alternatives Planning System model [13]. Because the Trend Extrapolation method is basing on the mathematical statistics of historical data, the subjective factors such as non-quantifiable factors and policy are not considered. That is, the qualitative analysis is not integrating into the quantitative analysis, so the long-term prediction results tend to produce large deviation. Scenario Analysis method, due to the combination of quantitative analysis and qualitative analysis of the characteristics, but also subjective factors such as non-quantifiable factors and the future of the various possible situations and the results of the maximum consideration. Scenario Analysis method has better predictive effect than other prediction methods such as Trend Extrapolation method, so it has been widely used by domestic and foreign scholars in mineral resource consumption forecast [14]. Chen et al. has used the VAR vector autoregressive model to predict the demand for Chinese steel [15].

This paper combines the two methods to predict the demand for China's copper in the next 15 years. We set out three scenarios of high, medium and low economic development in China (Table 1 and Table 2). The "S" shaped law of the per capita GDP and per capita copper consumption [16] will predict China's copper demand trends. In the middle scenario is 6.5% from 2016-2020, 6.0%from 2021-2025, and 5.5% from 2026-2030 [8].

Table 1. China's economic development trend forecast from 2016-2030

	GDP growth rate (%)			GDP(Trillion dollar)			
year	2016-2020	2021-2025	2026-2030	2016	2020	2025	2030
scenarios of high	7.0	6.5	6.0	12.10	15.86	21.73	29.08
scenarios of medium	6.5	6.0	5.5	11.50	14.78	19.80	25.88
scenarios of low	6.0	5.5	5.0	10.90	13.76	17.98	22.95

Table 2. China's population trends forecast from 2016-2030

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
total population (billion)	1.378	1.393	1.408	1.423	1.431	1.440	1.442	1.443	1.444	1.446
year	2026	2027	2028	2029	2030					
total population (billion)	1.449	1.452	1.455	1.458	1.462					

2. Methods

2.1. System Dynamics Model Based on Decomposition Method

Traditional factor decomposition of mineral resources consumption includes variables such as GDP, total consumption, and consumption intensity. The relationship between the variables can be expressed by a fully differential equation. Assume that *CON* represents the total annual

consumption of copper, *GDP* represents annual gross domestic product, then *CON* can be broken down into two indicators: Copper consumption intensity (*CON / GDP*) and GDP product, where *CON = CON / GDP * GDP*.

The total differential *dCON* equation for the total amount of copper consumption *CON* can be expressing as:

$$dCON=GDP*d(CON/GDP)+(CON/GDP)*dGDP \qquad (1)$$

Since the consumption intensity of copper is *INT = CON / GDP*, Equation (1) can be rewritten as

$$dCON=GDP*dINT+INT*dGDP \qquad (2)$$

According to the Equation (2), the system dynamics (*SD*) model of copper consumption is constructed. The model includes two traffic and multiple table functions, which can simulate the influencing factors of copper consumption and its effect.

As shown in Figure 1, the *SD* model has two cumulative variables as stock: the annual copper demand and *GDP*. The annual increase in the two stocks can be expressed in terms of flow rates, which correspond to the annual change in copper consumption (*dDemand*) and the annual change in *GDP* (*dGDP*) in the model. For the *dDemand* variable, according to the decomposition Equation (2), can be decomposed into (*GDP * dINT*) and (*INT * dGDP)* two combinations. In the *SD* model of Figure 1, Effect *GDP* and Effect *INT* are expressed, respectively. The *dINT* is represented by the variable *d* intensity in the model and is the derivative of the variable intensity.

In this *SD* model, the increment of *GDP* is set to the product of stock *GDP* and annual growth rate *GDP_gw*. GDP growth rate (*GDP_gw*) and copper consumption intensity are using in the form of table function. Annual copper consumption and annual *GDP* are both simulated values, and the actual value of the year actual consumption and actual *GDP* are different. Therefore, this paper sets two table functions *Error_D* and *Error_GDP*, respectively. That the annual copper consumption simulation and the actual value of the error, the annual *GDP* analog value and the actual *GDP* error.
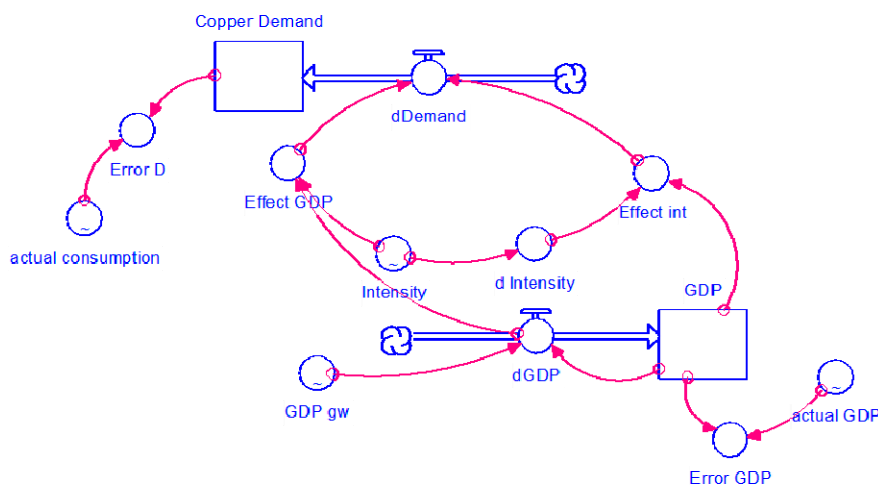

Figure 1. According to the decomposition method to build the copper consumption system dynamics model flow chart

Copper consumption decomposition method *SD* model, is the original analytical algorithm to support the decomposition method into a system dynamics model, you can achieve a model of multiple variables at the same time simulation, the consumption of copper, economic growth and other variables at the same time Dynamic Analysis.

The main simulation of the system dynamics model of the decomposition method is as follows:

*Copper_Demand(t) = Copper_Demand(t – dt) + (dDemand) * dt*

dDemand = (Effect_GDP+Effect_int)/10000

*GDP(t) = GDP(t – dt) + (dGDP) * dt*

*dGDP = GDP*GDP_gw/100*

d_Intensity = DERIVN(Intensity,1)

*Effect_GDP = dGDP*Intensity*

*Effect_int = GDP*d_Intensity*

Error_D = (Copper_Demand-actual_consumption)/Copper_Demand

Error_GDP = (GDP-actual_GDP)/GDP

In this model, for above procedures, the table function *actual_GDP* and *actual_consumption* by manually entering the calendar year value assignment. Table function intensity is also the actual value over the years, calculated from the actual *GDP* and copper consumption.

By constructing this model, we can analyze the relationship between copper consumption demand and *GDP* growth. Therefore, if we can qualitatively or quantitatively assume the growth of future *GDP*, and copper consumption intensity has a more accurate determination, you can use this model to predict the next few years China's copper consumption demand.

2.2 Copper Consumption Intensity Trend Forecast

In this paper, we use the historical consumption intensity data of China's copper to carry out the autoregressive moving average model (ARIMA) [17], and draw lessons from the copper consumption intensity and per capita *GDP* of the world's major industrialized countries "U" shape relationship between the forecast [16].

2.2.1 Based on ARIMA Model Prediction

Copper consumption intensity of ARIMA (5, 1, 4) is shown in Figure 2, in which blue lines represents historical values among 1955-2015, and red lines represents forecast value among 2016-2030.
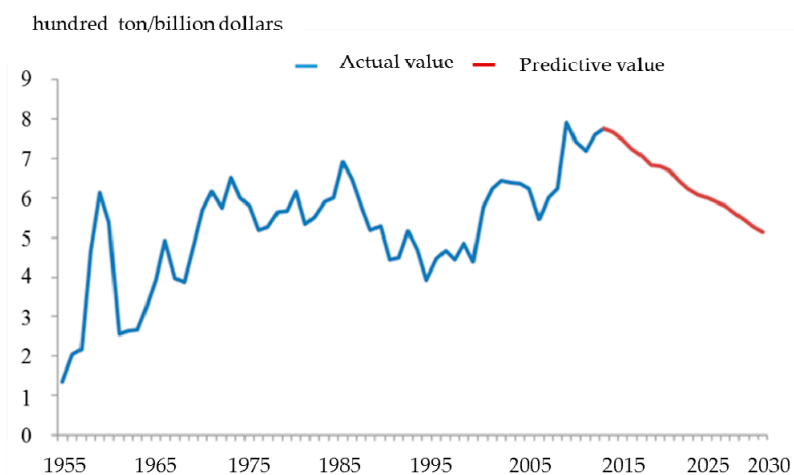

Figure 2. Forecast results of the copper consumption intensity ARIMA (5,1,4) model from 2016-2030

As shown in Figure 2, the future of China's copper consumption intensity showed a downward trend. By 2020, 2025 and 2030, respectively, 670.2 *t* / billion $, 611.2 *t* / billion $ and 511.2 *t* / billion $.

2.2.2 Based on Inverted U-Shaped Empirical Relationship Prediction

According to the literature [16] study shows that per capita *GDP* and copper consumption intensity between the inverted U-shaped empirical relationship. Based on this relationship, this study selected the *GDP* data of several industrialized countries and copper consumption intensity data to be fitted, obtained the empirical formula, and thus the prediction of China's copper consumption intensity, the results shown in Table 3.

Table 3. Forecast of China's Copper Consumption Intensity from 2016-2030

year	per capita GDP（$/ *person*）			copper consumption intensity（*t*/billion $）		
	high	medium	low	high	medium	low
2015		8332			713.7	
2016	8781	8345	7910	679.5	682.1	683.5
2017	9294	8792	8294	674.4	675.0	675.4
2018	9839	9264	8698	670.3	671.8	673.0
2019	10417	9762	9123	663.2	666.2	668.7
2020	11022	10271	9562	654.5	660.1	664.7
2021	11730	10880	10081	642.7	652.0	659.6
2022	12474	11517	10621	627.3	641.7	653.2
2023	13277	12199	11197	607.7	628.9	645.4
2024	14130	12922	11805	583.3	613.1	635.9
2025	15028	13693	12434	558.6	598.2	627.8
2026	15896	14416	13029	529.4	580.9	618.5
2027	16815	15178	13652	495.1	560.8	607.9
2028	17787	15979	14305	455.0	537.8	596.1
2029	18815	16824	14990	408.3	511.5	582.7
2030	19891	17702	15698	354.2	481.5	567.7

With the growth of per capita GDP, copper consumption intensity will show the first rise and fall after the development trend. In particular, for the high growth rate of per capita *GDP*, copper consumption intensity in 2020 after the rapid decline in 2030 may be reduced to 354.2 *t* /billion $. For intermediate reference, the copper consumption intensity was 660.1 *t* /billion $, 598.2 *t*/billion $ and 481.5 *t*/billion $ in 2020, 2025 and 2030, respectively. The results are similar to the predictions based on the ARIMA model.

2.3 China Copper Demand Forecast Results

In the process of data simulation, the choice of data period will often have an impact on the simulation results. After the study is optimized, the simulation is predicted from 1990-2015, and the model is constructed.

The predicted values of the copper consumption intensity trend is substituted into the system dynamics diagram shown in Figure 1, and the dynamic model of copper consumption demand under the three scenarios of high growth rate, medium speed and low speed of *GDP* growth is respectively carried out.

2.3.1 Forecast Results Based on ARIMA Model

The predictive results of the copper consumption demand with dynamics model based on ARIMA is shown in Table 4 and Figure 3.

Table 4. China's copper consumption demand forecast based on ARIMA copper consumption intensity system dynamics model

year	actual value	predictive value(10 *thousands t*)			year	predictive value(10 *thousands t*)		
		low	medium	high		low	medium	high
1990	72.90	72.90	72.90	72.90	2016	1157.39	1157.47	1157.42
1991	78.70	75.46	75.46	75.46	2017	1180.63	1190.81	1190.90
1992	99.30	81.47	81.47	81.47	2018	1201.48	1207.45	1203.42
1993	99.00	102.78	102.78	102.78	2019	1228.35	1251.49	1274.80
1994	91.00	102.78	102.78	102.78	2020	1295.21	1300.77	1326.74
1995	119.00	102.78	102.78	102.78	2021	1326.58	1370.77	1415.98
1996	127.00	131.75	131.76	131.76	2022	1326.58	1381.87	1440.87
1997	126.97	140.04	140.05	140.05	2023	1337.19	1406.15	1479.99
1998	139.74	140.04	140.05	140.05	2024	1354.14	1437.53	1527.26
1999	134.49	153.26	153.27	153.27	2025	1390.81	1490.55	1598.54
2000	192.81	153.26	153.27	153.27	2026	1409.97	1525.62	1651.73
2001	230.73	213.63	213.64	213.64	2027	1423.97	1550.08	1700.22
2002	268.44	252.87	252.88	252.88	2028	1422.66	1549.89	1700.19
2003	306.51	291.94	291.94	291.94	2029	1421.92	1548.33	1698.42
2004	336.39	331.35	331.37	331.37	2030	1418.45	1546.78	1696.94
2005	365.61	362.25	362.29	362.29				
2006	360.95	392.52	392.56	392.56				
2007	453.54	392.52	392.56	392.56				
2008	515.49	488.41	488.45	488.45				
2009	716.35	552.49	552.54	552.54				
2010	742.37	760.44	760.51	760.51				
2011	784.22	787.37	787.47	787.47				
2012	895.17	830.71	830.82	830.82				
2013	983.01	945.53	945.65	945.65				
2014	1130.30	1036.40	1036.53	1036.53				
2015	1145.10	1095.63	1095.76	1095.76				

Comparing the simulated values of the past year with the actual values, it can be seen that the simulation results are slightly larger than the difference before and after 2008 (the maximum error occurs in 2009, about 22%). The forecast value is the same as the actual consumption value, the error is mostly about 5%. A large error occurred around 2008, probably due to the global financial crisis that led to the actual consumption of copper and the economy, the population growth rate between the temporary decoupling.

Based on the ARIMA model, the prediction results of copper consumption demand dynamics model show that, in China's GDP high, medium and low growth, China's 2030 years ago, copper demand will tend to reach the point of the peak. Among them, the low growth rate of the most obvious. Under the low growth rate of GDP, China's copper consumption demand in 2027 can reach 14.24 Mt of peak platform period. In the case of medium-speed growth, China's copper consumption demand in 2028 close to the peak platform area, the demand peak value in 16 Mt or less. Only in the case of rapid growth, this trend has not yet appeared.
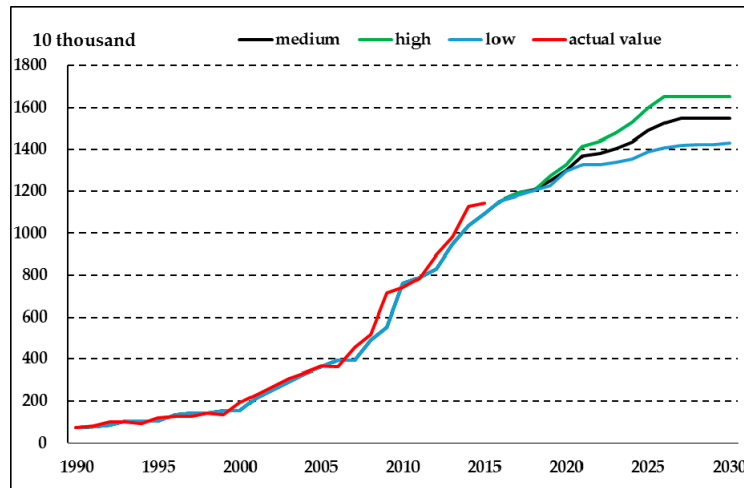
Figure 3. Prediction of China's copper consumption demand based on ARIMA model

2.3.2 Predictive Results Based on Inverted U– Shape Empirical Relation

The prediction results of the copper consumption demand with dynamics model based on the inverted U-type empirical relationship are shown in Figure 4 and Table 5. Whether it is high-speed *GDP*, medium speed, or low growth, China's copper consumption demand in 2030 years ago will reach the peak platform area, the peak value is 15.5 Mt.
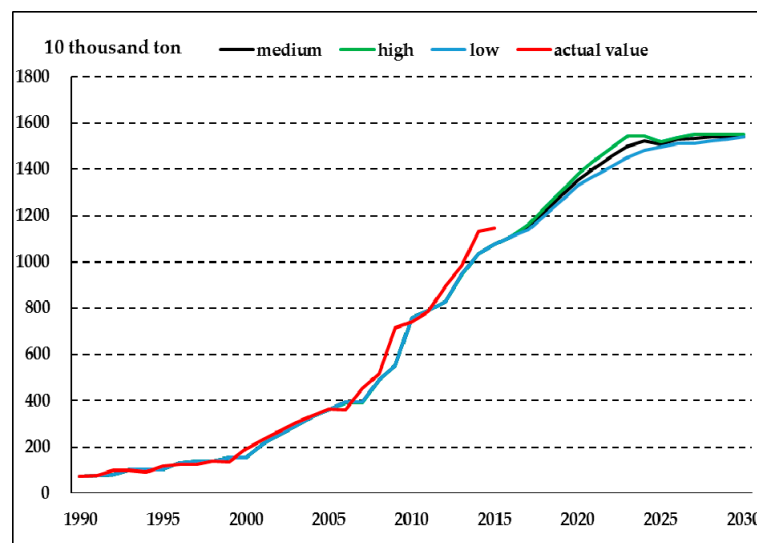

Figure 4. China's copper consumption demand forecast based on inverted U-shaped empirical relationship

If China's GDP to high-speed growth situation forward, then China's copper consumption demand will continue to maintain rapid growth, consumer demand will reach the peak in advance. In the case of high growth, China's copper consumption demand peaked at 2026, significantly faster than the medium and low speed, reaching 15.50 Mt, into the peak platform area. In the case of medium speed, China's copper demand peaked at 2027, with a peak of 15.41 Mt. Low-speed situation, even more slowly, about 2030 to reach the peak.

This predicts of copper demand in all areas of the national economy will continue to grow in the next 10 to 15 years, but the increase is obviously down.

Table 5. China's copper consumption demand forecast based on inverted U-shaped empirical relationship

Year	actual value	predictive value(10 *thousands t*)			year	predictive value(10 *thousands t*)		
		low	medium	high		low	medium	high
1990	72.90	72.90	72.90	72.90	2016	1109.17	1109.18	1109.04
1991	78.70	75.46	75.46	75.46	2017	1140.22	1150.37	1160.36
1992	99.30	81.47	81.47	81.47	2018	1202.76	1218.16	1233.34
1993	99.00	102.78	102.78	102.78	2019	1266.15	1286.67	1306.83
1994	91.00	102.78	102.78	102.78	2020	1329.53	1354.71	1379.22
1995	119.00	102.78	102.78	102.78	2021	1371.89	1406.34	1439.21
1996	127.00	131.76	131.76	131.75	2022	1413.37	1455.85	1494.98
1997	126.97	140.05	140.05	140.04	2023	1453.41	1502.04	1544.16
1998	139.74	140.05	140.05	140.04	2024	1481.38	1523.43	1543.72
1999	134.49	153.27	153.27	153.26	2025	1496.52	1508.23	1519.91
2000	192.81	153.27	153.27	153.26	2026	1510.86	1528.28	1550.51
2001	230.73	213.64	213.64	213.63	2027	1512.62	1541.68	1550.51
2002	268.44	252.88	252.88	252.87	2028	1521.28	1541.68	1550.51
2003	306.51	291.94	291.94	291.94	2029	1530.23	1541.68	1550.51
2004	336.39	331.37	331.37	331.35	2030	1540.81	1541.68	1550.51
2005	365.61	362.29	362.29	362.25				
2006	360.95	392.56	392.56	392.52				
2007	453.54	392.56	392.56	392.52				
2008	515.49	488.45	488.45	488.41				
2009	716.35	552.54	552.54	552.49				
2010	742.37	760.51	760.51	760.44				
2011	784.22	787.47	787.47	787.37				
2012	895.17	830.82	830.82	830.71				
2013	983.01	945.65	945.65	945.53				
2014	1130.30	1036.40	1036.53	1036.53				
2015	1145.10	1076.40	1076.53	1076.53				

3. Results and Analysis

In this paper, the method of predicting copper consumption dynamics model based on decomposition method is using to determine the trend of copper consumption intensity in China. But also the use of departmental consumption law, quantitative forecasting and qualitative judgments, the results shown in Table 6.

For the prediction of copper consumption intensity, one is basing on the ARIMA model of the forecasting, the second is basing on other industrialized countries inverted U-type consumption of the forecast. For the first use of ARIMA model value, in the case of low GDP growth, China's copper consumption demand in 2025 gradually reached its peak, and in 2027-2030 stable at 14.2 Mt of high platform, the same period, high growth continue to maintain a slight growth (Table 4, Figure 3). For the second copper consumption intensity with inverted U-shaped consumption experience, it shows that the gap between the three *GDP* growth increases first, then gradually narrows and tends to be consistent (Table 5, Figure 4).

Different methods or methods, the predicted values of the time nodes are different, the short-term forecast value tends to be consistent, and the medium and long-term forecast values are different. Therefore, based on the comprehensive comparison of the predicted results of the above methods, the prediction value of the system dynamics model is the main factor, the other method predictions are the important reference, and finally the comprehensive reference value is obtained.

The results show that in 2020, 2025 and 2030 were 13 Mt, 15 Mt and 15.5 Mt. From 2015 to 2030, China's copper consumption demand showed a gradual slowdown in the growth rate, and in 2030 years before entering the peak platform period. Copper demand growth of about 3 Mt from 2015 to 2020, and copper demand growth of about 2 Mt from 2020 to 2025, copper demand growth of about 0.5 Mt from 2025 to 2030.

Since the Chinese economy has entered a new norm in 2015, China's demand for commodities is changing. Raw materials are closely relate to construction and infrastructure, and steel, iron ore and coal mineral, known as "early cycle" commodities, are most susceptible. The copper metal, which closely follows China's economic data, has been affected, with trading prices falling to its lowest level in less than five years (less than $ 6000/t). Macquarie is expected to grow in demand in China, the situation, the 2019 copper market supply surplus will reach 2 Mt. For miners, this will remove the need for new capacity. In other words, the copper boom of this round is bound to end, 2015-2020 years ago, China's copper demand compared to the previous rapid rise, will maintain a low growth momentum. The results of this study are confirm by this.

Table 6. Comparison of the results of a combination of multiple methods or methods for China's copper consumption demand forecast   unit: *10 thousands t*

methods		2016		2020		2025		2030	
		range	reference	range	reference	range	reference	range	reference
copper consump-tion system dynamics model	based on the ARIMA model correction value to prediction copper consumption intensity	1065	1065	1295-1326	1300	1390-1598	1490	1423-1789	1591
	copper consumption intensity based on inverted U–shaped empirical relation prediction	1109	1109	1329-1379	1354	1496-1519	1508	1540-1550	1542
partial consumption forecast		1083		1383		1600		1580	
comprehensive reference value		1050		1300		1500		1550	

It is expect that by 2020, China's power industry will decline in copper, but with China's economic structure optimization and adjustment, industrial upgrading is about complete, the central and western regions into the rapid development track. Daily consumer goods, information, electronic communications industry, transportation, machinery manufacturing and other areas of the total amount of copper will be a certain degree of growth, for make up even more than the power industry with the amount of copper reduction. It is judged that China's copper consumption demand may continue to maintain a relatively low growth rate, reaching about 15 Mt around 2025. 2027 is the peak year of China's copper consumption demand, which consumption demand peak value will be about 15.5 Mt, and 15.4 Mt in 2030.

4. Results and Conclusion

In summary, the future of China's copper consumption demand will continue to be subject to multiple factors, mainly in the following areas:

(1) Economic growth is still pulling the core elements of mineral resource consumption, the world economy continued to increase dependence on resource consumption has not fundamentally changed. Under the new norm, China's future economic growth drivers will not change fundamentally. The eastern part of the industrial upgrading and the rapid development of new urbanization in the Midwest, the Chinese economy is expect to maintain a steady growth in a long period time. Its demand for basic metal consumption growth trend is stable.

(2) China's copper consumption is also growing, if all can be recycled, will ease the domestic copper supply and demand contradiction play an important role. In accordance with the average life of copper products in developed countries 30 years, 70% of the recovery rate of scrap copper to calculate by 2020, the amount of waste copper can be recycled to reach 2.2 Mt, equivalent to all the copper products forecast demand about 20%.

(3) Urbanization rate to accelerate the growth of copper demand to further increase the space, the urbanization rate is likely to increase by 1 percentage point per year to 2020 will reach 60%.

(4) In 2016, China's apparent consumption of copper amounted to 11.51 Mt. In which, the electricity industry accounted for 42% of the national copper consumption, consumer goods accounted for 15%, electronic communications accounted for 15%, machine manufacture industry accounted for 10%, 8% of transportation, construction industry accounted for 3%, other industries accounted for 7%. Compared with the consumption structure of the developed countries in the world, China's copper consumption in the field of construction, transportation and other areas continued to grow. It is expect that domestic demand for copper may reach 13.0 Mt in 2020, may reach 15.0 Mt in 2025, and may reach 15.5 Mt in 2030.

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Conflicts of Interest: The authors declare no conflict of Internet.

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