

Supporting Information (SI)

Examining the Temporal Demand and Sustainability of Copper in China

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1. Substance flow of copper

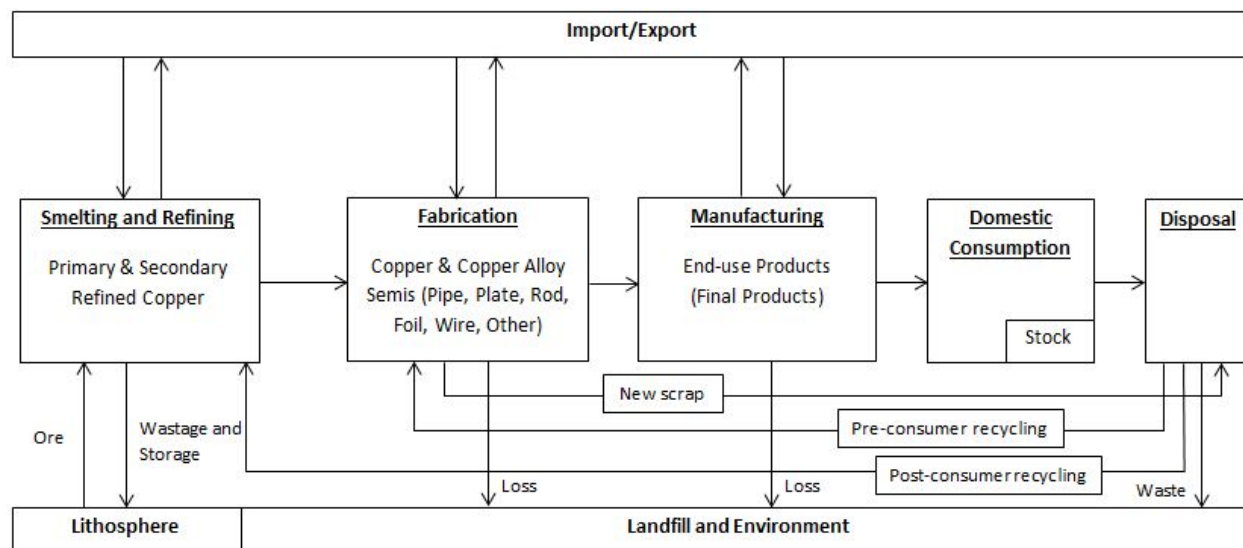


Figure S1. Adopted substance flow of copper for China in the research.

Figure S1 shows how copper is being circulated across different industrial processes within China's anthrosphere. The actual substance flow of copper is more comprehensive than the presented figure. This research was performed under the framework of time series analysis; thus, a major challenge was the collection of yearly data between 1950 and 2015, since more detailed data about each process step was not recorded in statistical sources (e.g. historical data, losses during production, import and export quantities, new scrap generation, etc). Therefore, above flow chart is used to conduct the analysis. It provides a reliable and impartial estimate to link the historical and present context of copper flow in China.

In the anthropogenic copper cycle, ore is separated from reserves and concentrated to extract large quantities of copper at the first stage. Secondly, accumulated copper is subjected to smelting and refining processes to increase its purity. Then, refined copper is directed to industrially important steps of fabrication and manufacturing. Importations are also added to all industrial process steps. A portion of products is exported to other countries for income generation. A larger amount of manufactured output is domestically consumed and a substantial

portion of end-use products is also exported to demanded countries. Recycling is practiced at the disposal stage (new scrap and old scrap) to enhance the secondary production which is illustrated in the figure. A portion of old scrap disposed after the consumption period is subjected to secondary production and rest is released to landfills. Annually generated new scrap is directed to both pre-consumer and post-consumer recycling steps which constitute high grade and low grade copper scrap respectively. However, it should be noted that copper wastage occurs alongside different substance flow steps.

2. Methods and data sources used in the study

2.1. Determination of copper quantity of products

The copper quantity of each product stock within the stipulated time is calculated through following equation.

$$P_{i,t} = (P_{i, t,ave} \times N_{i, t} \times L_{i, t}) \quad \text{Eq. (S1)}$$

Where $P_{i,t}$ is the copper quantity of product i stock at time t , $P_{i, t,ave}$ is the average quantity of product i , $N_{i, t}$ is the number of i products at time t , and $L_{i, t}$ is the copper content of the product i .

2.2. Adopted assumptions for historical demand and supply determination

With the exception of the assumptions used to determine pre-consumer recycling, other assumptions were made by observing patterns in the data from previous years.

- i. For 1979 to 1996, refined imports = refined consumption - refined production + refined exports.
- ii. 2008-2015 refined consumption was 125% of refined production in the same period.
- iii. Copper content of semis is assumed as 0.86.¹
- iv. 1950-1989 net imports of semis were zero, 1990-1996 imports of semis were 30% of refined production, 1990-1996 exports of semis were 5×10000 tons.

- v. 1950-1978 imports of end-uses were too small, so that it is assumed as zero.
- vi. 1979-1993 imports of end-uses are assumed as 8.5% from refined consumption in the same period observing data pattern of 1995-2007.
- vii. 1950-1978 exports of end-uses were too small, so that it is assumed as zero.
- viii. 1979-1989 exports of end-uses were 15% of demand at the same period.
- ix. 1990-1996 exports of end-uses were 50% of demand at the same period.
- x. Quantity of copper scrap generated in a year = 15% of refined production in the same year.
- xi. Fabrication loss = 1.5% of refined production.
- xii. Manufacturing loss is assumed to be negligible, according to the International Copper Association (ICA).
- xiii. 1950-1978 pre-consumer recycling (i.e., high grade scrap) is assumed to be negligible.
- xiv. For 1979-2015, pre-consumer recycling = (new scrap)/2.

Table S1. Grouping ratios for copper end-use products in China.

Year	Building & construction	Infrastructure	Transportation	Industrial & other equipment	References
1950–1959	1	45	1	53	(1)
1960–1969	1	39	1	59	
1970–1979	1	38	1	60	
1980–1989	5	50	5	40	
1990–1999	9	46	11	34	
2000–2050	24	18	12	46	(2)

Table S2. Calculations of equation 1 (Unit: Mt).

Year	D_x	R_x^c	$\sum_{b=1}^n F_{b,x}^{i,e}$	$\sum_{d=1}^n M_{d,x}^i$	G_x^c	$\sum_{f=1}^n M_{f,x}^e$
1953	0.036	0.036	0.000	0.000	0.036	0.000
1954	0.033	0.033	0.000	0.000	0.033	0.000
1955	0.037	0.037	0.000	0.000	0.037	0.000
1956	0.060	0.060	0.000	0.000	0.060	0.000
1957	0.069	0.069	0.000	0.000	0.069	0.000
1958	0.163	0.163	0.000	0.000	0.163	0.000
1959	0.217	0.217	0.000	0.000	0.217	0.000
1960	0.185	0.185	0.000	0.000	0.185	0.000
1961	0.072	0.072	0.000	0.000	0.072	0.000
1962	0.075	0.075	0.000	0.000	0.075	0.000
1963	0.083	0.083	0.000	0.000	0.083	0.000
1964	0.113	0.113	0.000	0.000	0.113	0.000
1965	0.153	0.153	0.000	0.000	0.153	0.000
1966	0.210	0.210	0.000	0.000	0.210	0.000
1967	0.164	0.164	0.000	0.000	0.164	0.000
1968	0.157	0.157	0.000	0.000	0.157	0.000
1969	0.210	0.210	0.000	0.000	0.210	0.000
1970	0.280	0.280	0.000	0.000	0.280	0.000
1971	0.319	0.319	0.000	0.000	0.319	0.000
1972	0.307	0.307	0.000	0.000	0.307	0.000
1973	0.373	0.373	0.000	0.000	0.373	0.000
1974	0.350	0.350	0.000	0.000	0.350	0.000
1975	0.358	0.358	0.000	0.000	0.358	0.000

1976	0.319	0.319	0.000	0.000	0.319	0.000
1977	0.344	0.344	0.000	0.000	0.344	0.000
1978	0.408	0.408	0.000	0.000	0.408	0.000
1979	0.481	0.443	0.000	0.038	0.409	0.072
1980	0.539	0.497	0.000	0.042	0.458	0.081
1981	0.495	0.456	0.000	0.039	0.421	0.074
1982	0.550	0.507	0.000	0.043	0.468	0.083
1983	0.638	0.588	0.000	0.050	0.542	0.096
1984	0.731	0.674	0.000	0.057	0.622	0.110
1985	0.928	0.855	0.000	0.073	0.789	0.139
1986	0.928	0.855	0.000	0.073	0.789	0.139
1987	0.916	0.844	0.000	0.072	0.778	0.137
1988	0.880	0.811	0.000	0.069	0.748	0.132
1989	0.910	0.839	0.000	0.071	0.774	0.137
1990	0.909	0.729	0.118	0.062	0.454	0.454
1991	0.972	0.787	0.118	0.067	0.486	0.486
1992	1.225	0.993	0.148	0.084	0.613	0.613
1993	1.243	0.990	0.169	0.084	0.622	0.622
1994	1.212	0.910	0.171	0.131	0.606	0.606
1995	1.574	1.190	0.274	0.110	0.787	0.787
1996	1.661	1.270	0.286	0.105	0.831	0.831
1997	1.710	1.270	0.331	0.109	0.670	1.040
1998	1.897	1.397	0.390	0.110	0.132	1.765
1999	1.915	1.345	0.456	0.115	-0.054	1.970
2000	2.606	1.928	0.513	0.165	0.523	2.083
2001	3.008	2.307	0.530	0.170	0.862	2.146
2002	3.503	2.684	0.642	0.177	1.106	2.398
2003	3.958	3.065	0.708	0.185	1.348	2.610
2004	4.244	3.364	0.688	0.192	1.405	2.839
2005	4.407	3.656	0.565	0.186	1.451	2.956

2006	4.257	3.610	0.457	0.191	1.042	3.215
2007	5.200	4.535	0.477	0.188	1.769	3.430
2008	5.272	4.724	0.359	0.189	1.957	3.315
2009	5.709	5.213	0.314	0.183	3.118	2.591
2010	6.381	5.838	0.346	0.198	3.217	3.164
2011	6.896	6.450	0.242	0.205	3.715	3.182
2012	7.706	7.350	0.151	0.205	4.682	3.025
2013	8.680	8.338	0.139	0.204	5.649	3.031
2014	9.875	9.563	0.083	0.230	6.822	3.054
2015	10.374	9.950	0.084	0.340	7.363	3.011

Table S3. Calculations of equations 2 & 3 (Unit: Mt).

Year	S_x	Q_x	R_x^p	R_x^i	$\sum_{b=1}^n F_{b,x}^i$	H_x^r	h_x^r	W_x^n	F_x^l	M_x^l
1950	0.023	0.015	0.003	0.014	0.000	0.008	0.000	0.002	0.0002	0.000
1951	0.027	0.010	0.004	0.009	0.000	0.018	0.000	0.003	0.0003	0.000
1952	0.033	0.008	0.005	0.008	0.000	0.025	0.000	0.004	0.0004	0.000
1953	0.036	0.002	0.007	0.002	0.000	0.034	0.000	0.006	0.0006	0.000
1954	0.057	0.019	0.009	0.018	0.000	0.038	0.000	0.007	0.0007	0.000
1955	0.052	0.016	0.012	0.012	0.000	0.037	0.000	0.007	0.0007	0.000
1956	0.091	0.039	0.019	0.033	0.000	0.052	0.000	0.011	0.0011	0.000
1957	0.062	0.031	0.022	0.018	0.000	0.031	0.000	0.008	0.0008	0.000
1958	0.109	0.071	0.033	0.050	0.000	0.038	0.000	0.011	0.0011	0.000
1959	0.208	0.135	0.044	0.110	0.000	0.073	0.000	0.018	0.0018	0.000
1960	0.158	0.114	0.057	0.074	0.000	0.044	0.000	0.015	0.0015	0.000

1961	0.052	0.035	0.036	0.008	0.000	0.017	0.000	0.008	0.0008	0.000
1962	0.057	0.043	0.044	0.008	0.000	0.014	0.000	0.009	0.0009	0.000
1963	0.071	0.046	0.054	0.005	0.000	0.025	0.000	0.012	0.0012	0.000
1964	0.117	0.081	0.071	0.028	0.000	0.035	0.000	0.016	0.0016	0.000
1965	0.178	0.139	0.094	0.067	0.000	0.039	0.000	0.020	0.0020	0.000
1966	0.219	0.182	0.122	0.087	0.000	0.037	0.000	0.024	0.0024	0.000
1967	0.183	0.156	0.077	0.096	0.000	0.028	0.000	0.016	0.0016	0.000
1968	0.134	0.110	0.052	0.071	0.000	0.023	0.000	0.011	0.0011	0.000
1969	0.237	0.210	0.100	0.132	0.000	0.026	0.000	0.019	0.0019	0.000
1970	0.270	0.238	0.133	0.132	0.000	0.032	0.000	0.025	0.0025	0.000
1971	0.277	0.242	0.172	0.105	0.000	0.035	0.000	0.031	0.0031	0.000
1972	0.303	0.269	0.207	0.101	0.000	0.034	0.000	0.036	0.0036	0.000
1973	0.421	0.385	0.237	0.193	0.000	0.035	0.000	0.041	0.0041	0.000
1974	0.369	0.323	0.189	0.173	0.000	0.046	0.000	0.035	0.0035	0.000
1975	0.328	0.276	0.206	0.113	0.000	0.052	0.000	0.039	0.0039	0.000
1976	0.265	0.215	0.187	0.067	0.000	0.050	0.000	0.036	0.0036	0.000
1977	0.312	0.260	0.213	0.091	0.000	0.052	0.000	0.040	0.0040	0.000
1978	0.366	0.302	0.235	0.116	0.000	0.064	0.000	0.045	0.0045	0.000
1979	0.450	0.347	0.259	0.106	0.000	0.078	0.025	0.051	0.0051	0.000
1980	0.506	0.394	0.278	0.133	0.000	0.085	0.027	0.055	0.0055	0.000
1981	0.461	0.315	0.270	0.071	0.000	0.117	0.029	0.058	0.0058	0.000
1982	0.522	0.386	0.242	0.159	0.000	0.110	0.026	0.053	0.0053	0.000
1983	0.605	0.474	0.267	0.218	0.000	0.103	0.028	0.056	0.0056	0.000
1984	0.696	0.558	0.284	0.282	0.000	0.109	0.029	0.059	0.0059	0.000
1985	0.891	0.752	0.305	0.442	0.000	0.107	0.031	0.062	0.0062	0.000
1986	0.887	0.743	0.346	0.399	0.000	0.110	0.034	0.068	0.0068	0.000
1987	0.874	0.691	0.372	0.333	0.000	0.145	0.039	0.078	0.0077	0.000
1988	0.881	0.641	0.325	0.335	0.000	0.201	0.039	0.079	0.0079	0.000
1989	0.871	0.604	0.336	0.289	0.000	0.226	0.042	0.084	0.0084	0.000
1990	0.925	0.671	0.347	0.187	0.168	0.212	0.042	0.084	0.0084	0.000

1991	0.978	0.747	0.371	0.234	0.168	0.189	0.042	0.084	0.0084	0.000
1992	1.227	0.938	0.420	0.345	0.198	0.240	0.049	0.099	0.0099	0.000
1993	1.233	0.933	0.485	0.266	0.219	0.245	0.055	0.110	0.0110	0.000
1994	1.211	0.889	0.469	0.189	0.221	0.267	0.055	0.110	0.0110	0.000
1995	1.566	1.018	0.612	0.150	0.324	0.467	0.081	0.162	0.0162	0.000
1996	1.652	1.140	0.692	0.192	0.336	0.428	0.084	0.168	0.0168	0.000
1997	1.810	1.343	0.801	0.211	0.417	0.379	0.089	0.177	0.0177	0.000
1998	1.971	1.539	0.871	0.288	0.470	0.341	0.091	0.182	0.0182	0.000
1999	2.274	1.848	0.836	0.548	0.543	0.338	0.088	0.176	0.0176	0.000
2000	2.862	2.412	1.023	0.812	0.637	0.348	0.103	0.206	0.0206	0.000
2001	3.147	2.726	1.216	0.954	0.637	0.307	0.114	0.229	0.0228	0.000
2002	3.782	3.279	1.252	1.330	0.789	0.380	0.122	0.245	0.0245	0.000
2003	4.326	3.762	1.411	1.562	0.908	0.426	0.138	0.275	0.0275	0.000
2004	4.597	3.813	1.579	1.381	1.023	0.620	0.165	0.330	0.0330	0.000
2005	4.931	3.992	1.856	1.415	0.963	0.744	0.195	0.390	0.0390	0.000
2006	4.831	3.606	2.004	0.969	0.937	0.999	0.225	0.451	0.0450	0.000
2007	6.008	4.609	2.362	1.730	0.906	1.136	0.262	0.525	0.0525	0.000
2008	6.132	4.768	2.699	1.700	0.804	1.081	0.283	0.567	0.0567	0.000
2009	8.153	6.440	2.770	3.470	0.705	1.400	0.313	0.626	0.0626	0.000
2010	8.612	6.562	2.970	3.382	0.783	1.700	0.350	0.701	0.0701	0.000
2011	8.864	6.627	3.310	3.291	0.672	1.850	0.387	0.774	0.0774	0.000
2012	10.110	7.759	3.970	3.979	0.575	1.910	0.441	0.882	0.0882	0.000
2013	10.676	8.196	4.690	3.843	0.559	1.980	0.500	1.001	0.1001	0.000
2014	11.932	8.528	4.820	4.221	0.519	2.830	0.574	1.148	0.1148	0.000
2015	12.314	8.717	4.960	4.245	0.484	3.000	0.597	1.194	0.1194	0.000

Table S4. Copper content of end-use products.

End-use product	Average weight (kg/Unit)	Copper content	References
Television (TV)		1 kg/Unit	(1), (3)
Mobile phone	0.1	10% per unit	(1), (4), (5)
Radio	2	10% per unit	(4), (5), (6)
Motor car		20 kg/Unit	(1), (3)
Small passenger vehicle	900	1.5% per unit	(6)
Truck	36000	1% per unit	(6)
Dump truck	15000	1% per unit	(6)
Electric motors and generators		0.4 kg/Unit	(1), (3)
Airplane	89000	2.4% per unit	(6)
Ship	50000000	1% per unit	(6)
TV Monitor	10	1% per unit	Derived from TV copper content of (7)
Refrigerator		1.5 kg/Unit	(1), (3)
Boat	1000	1% per unit	(6)
Compressor		2.5 kg/Unit	(1), (3)
Computer	14.9-25	6.5% per unit	(4), (7), (8)
Electric fan	2.5	18% per unit	(6)
Insulated electric wire and cable		25% of total stock weight per year	(1), (3)
Copper hardware		10% of total stock weight per year	
Capacitor		13.5% of total stock weight per year	(6)
Battery	0.08	11% per unit	
Bicycle	8	1% per unit	
Sewing machine	1997-1999: 13.6 2000 onwards: 8	3% per unit	(6)
Camera	0.35	10% per unit	Assumption: copper content is equal to a mobile phone's copper content

Table S5. Projected Chinese population from 2016 to 2050, under three population variants.

Year	High population variant	Medium population variant	Low population variant
2016	1378487466	1374785172	1370945756
2017	1385971925	1382249529	1378389267
2018	1393742894	1389999627	1386117721
2019	1401129731	1393613626	1385840497
2020	1406874363	1395146601	1382791648
2021	1412642548	1396681262	1379749507
2022	1418434382	1398217612	1376714058
2023	1424249963	1399755651	1373685287
2024	1430089388	1401295382	1370663179
2025	1435952754	1402836807	1367647720
2026	1435952754	1402836807	1367647720
2027	1435952754	1402836807	1367647720
2028	1435952754	1402836807	1367647720
2029	1435952754	1402836807	1367647720
2030	1437819493	1400451984	1360946246
2031	1439688658	1398071216	1354277610
2032	1441560253	1395694495	1347641650
2033	1443434282	1393321814	1341038205
2034	1445310746	1390953167	1334467118
2035	1447189650	1388588547	1327928229
2036	1447189650	1388588547	1327928229
2037	1447189650	1388588547	1327928229
2038	1447189650	1388588547	1327928229
2039	1447189650	1388588547	1327928229
2040	1447334369	1382617616	1316375254
2041	1447479102	1376672360	1304922789
2042	1447623850	1370752669	1293569961
2043	1447768613	1364858433	1282315902
2044	1447913390	1358989542	1271159754
2045	1448058181	1353145887	1260100664
2046	1448058181	1353145887	1260100664
2047	1448058181	1353145887	1260100664
2048	1448058181	1353145887	1260100664
2049	1448058181	1353145887	1260100664
2050	1446899734	1344485753	1244727436

Note: Population variants are derived from publications of the United Nations.^{9,10,11}

2.3. G_{x-K}^c determination

Example: K = short/medium/long life span of end-use groups in years. For this example, we use the medium life span of end-use group “building & construction”, which is given as 30 years (K) in Table S6. When we consider $x=2015$, G_{x-K}^c is equal to the copper domestic consumption of 1985, which is the EoL waste quantity generated in 2015 under medium life span of building & construction category. We calculate the domestic consumption (G_x^c) from 1950 to 2015 using equation 1 in the main paper. Projection procedures of G_x^c between 2015 and 2050 are similar to the primary copper demand predictions discussed in 2.3.1 and 2.3.2 sections of the main paper. Accordingly, we also calculated G_{x-K}^c of other end-use groups and finally summed them to determine a total value of G_{x-K}^c . In this way, we calculated total G_{x-K}^c for all life span categories of end-use groups.

2.4. Forecasting domestic and total demand via population variants and demand growth rates

The projection procedure of domestic demand from 2016 to 2050 is interpreted as follows:

(1) Forecasting domestic demand

For the per capita demand determination from 2000 to 2015, the calculated domestic demand for each year in the study was directly divided by relevant yearly population statistics shown in World Bank, 2018.¹² Using the 2015 per capita demand as the baseline, this value was multiplied by the annual population variant and annual metal demand growth rate to forecast domestic demand from 2016 to 2030. We assumed copper demand growth rate will peak in 2030 and remain constant thereafter, because both foreign and Chinese specialists forecast that the copper usage in China will almost reach the peak between 2025 and 2030.^{1,13} The subcategories adopted in this part are given below:

- Factual demand: calculated demand from 2000 to 2015

Determination of copper domestic demand scenarios between 2015 and 2030:

Domestic demand scenarios of year 2016

- High-stable: high population variant in year 2016 \times 5.4 kg/capita (calculated value for 2015). Here, it is assumed that demand growth rate will be steady-state.
- Medium-stable: medium population variant in year 2016 \times 5.4 kg/capita (calculated value for 2015). Here, it is assumed that demand growth rate will be steady-state.
- Low-stable: low population variant in year 2016 \times 5.4 kg/capita (calculated value for 2015). Here, it is assumed that demand growth rate will be steady-state.
- High-2.5%: high population variant in year 2016 \times 5.4 kg/capita \times 1.025
- Medium-2.5%: medium population variant in year 2016 \times 5.4 kg/capita \times 1.025
- Low-2.5%: low population variant in year 2016 \times 5.4 kg/capita \times 1.025
- High-3.5%: high population variant in year 2016 \times 5.4 kg/capita \times 1.035
- Medium-3.5%: medium population variant in year 2016 \times 5.4 kg/capita \times 1.035
- Low-3.5%: low population variant in year 2016 \times 5.4 kg/capita \times 1.035
- High-4.5%: high population variant in year 2016 \times 5.4 kg/capita \times 1.045
- Medium-4.5%: medium population variant in year 2016 \times 5.4 kg/capita \times 1.045
- Low-4.5%: low population variant in year 2016 \times 5.4 kg/capita \times 1.045

Domestic demand scenarios of year 2017

- High-stable: high population variant in year 2017 \times 5.4 kg/capita (calculated value for 2015). Here, it is assumed that demand growth rate will be steady-state.
- Medium-stable: medium population variant in year 2017 \times 5.4 kg/capita (calculated value for 2015). Here, it is assumed that demand growth rate will be steady-state.

- Low-stable: low population variant in year 2017 \times 5.4 kg/capita (calculated value for 2015). Here, it is assumed that demand growth rate will be steady-state.
- High-2.5%: high population variant in year 2017 \times 5.4 kg/capita \times (1.025)²
- Medium-2.5%: medium population variant in year 2017 \times 5.4 kg/capita \times (1.025)²
- Low-2.5%: low population variant in year 2017 \times 5.4 kg/capita \times (1.025)²
- High-3.5%: high population variant in year 2017 \times 5.4 kg/capita \times (1.035)²
- Medium-3.5%: medium population variant in year 2017 \times 5.4 kg/capita \times (1.035)²
- Low-3.5%: low population variant in year 2017 \times 5.4 kg/capita \times (1.035)²
- High-4.5%: high population variant in year 2017 \times 5.4 kg/capita \times (1.045)²
- Medium-4.5%: medium population variant in year 2017 \times 5.4 kg/capita \times (1.045)²
- Low-4.5%: low population variant in year 2017 \times 5.4 kg/capita \times (1.045)²

According to this pattern, we repeated our calculations on domestic demand up to 2030. Here, we have also included equations of 2030 for a clear understanding of the method.

Domestic demand scenarios of year 2030

- High-stable: high population variant in year 2030 \times 5.4 kg/capita (calculated value for 2015). Here, it is assumed that demand growth rate will be steady-state.
- Medium-stable: medium population variant in year 2030 \times 5.4 kg/capita (calculated value for 2015). Here, it is assumed that demand growth rate will be steady-state.
- Low-stable: low population variant in year 2030 \times 5.4 kg/capita (calculated value for 2015). Here, it is assumed that demand growth rate will be steady-state.
- High-2.5%: high population variant in year 2030 \times 5.4 kg/capita \times (1.025)¹⁵
- Medium-2.5%: medium population variant in year 2017 \times 5.4 kg/capita \times (1.025)¹⁵
- Low-2.5%: low population variant in year 2030 \times 5.4 kg/capita \times (1.025)¹⁵

- High-3.5%: high population variant in year 2030 $\times 5.4 \text{ kg/capita} \times (1.035)^{15}$
- Medium-3.5%: medium population variant in year 2030 $\times 5.4 \text{ kg/capita} \times (1.035)^{15}$
- Low-3.5%: low population variant in year 2030 $\times 5.4 \text{ kg/capita} \times (1.035)^{15}$
- High-4.5%: high population variant in year 2030 $\times 5.4 \text{ kg/capita} \times (1.045)^{15}$
- Medium-4.5%: medium population variant in year 2030 $\times 5.4 \text{ kg/capita} \times (1.045)^{15}$
- Low-4.5%: low population variant in year 2030 $\times 5.4 \text{ kg/capita} \times (1.045)^{15}$

Since we assume that demand growth rate will remain constant after 2030, we used the following equations to calculate domestic demand scenarios between 2030 and 2050.

- High-stable: high population variant in year $x \times 5.4 \text{ kg/capita}$ (calculated value for 2015).
Here, it is assumed that demand growth rate will be steady-state.
- Medium-stable: medium population variant in year $x \times 5.4 \text{ kg/capita}$ (calculated value for 2015). Here, it is assumed that demand growth rate will be steady-state.
- Low-stable: low population variant in year $x \times 5.4 \text{ kg/capita}$ (calculated value for 2015).
Here, it is assumed that demand growth rate will be steady-state.
- High-2.5%: high population variant in year $x \times 5.4 \text{ kg/capita} \times (1.025)^{15}$
- Medium-2.5%: medium population variant in year 2017 $\times 5.4 \text{ kg/capita} \times (1.025)^{15}$
- Low-2.5%: low population variant in year $x \times 5.4 \text{ kg/capita} \times (1.025)^{15}$
- High-3.5%: high population variant in year $x \times 5.4 \text{ kg/capita} \times (1.035)^{15}$
- Medium-3.5%: medium population variant in year $x \times 5.4 \text{ kg/capita} \times (1.035)^{15}$
- Low-3.5%: low population variant in year $x \times 5.4 \text{ kg/capita} \times (1.035)^{15}$
- High-4.5%: high population variant in year $x \times 5.4 \text{ kg/capita} \times (1.045)^{15}$
- Medium-4.5%: medium population variant in year $x \times 5.4 \text{ kg/capita} \times (1.045)^{15}$
- Low-4.5%: low population variant in year $x \times 5.4 \text{ kg/capita} \times (1.045)^{15}$

Here, only variable influenced to domestic demand change is the population variant of relevant year.

(2) Forecasting total demand

The total demand for copper in China from 2016 to 2050 was also predicted according to the methodology adopted in domestic demand forecasting. We found that per capita demand for copper is around 7.6 kg for 2015 after using the equation 1 shown in the main paper and population statistics since exports should be also included in the total demand estimation. Only difference is the substitution of calculated per capita total demand in 2015 (7.6 kg) to the 5.4 kg in equations of 2.4. (1).

(3) Uncertainty assessment

Generally, the population variants (see Table S5) are well reported by the *United Nations World Population Prospects* and their data quality is comparatively high. According to their guidelines, population changes will be relatively very small and population will keep on a basically similar phase from 2016 to 2050 in China. After 2030, we assumed that the annual demand growth rate will remain constant; thus, only factor that is influenced to the demand increase or decrease is the corresponding population variant. Since we used three population variants, i.e., low, medium, and high in the study, we believe that the precision of results is managed to an acceptable level in the scenario analysis. However, we performed an uncertainty analysis for high-4.5% scenario as a sample to verify the accuracy of domestic and total demand estimations.

The demand estimations are taken into account to model the uncertain possibilities under the normal distribution considering their output quality. To generate ranges of random upshots between 2030 and 2050, the simulation model runs 10,000 times. Since the deviation range of

the high population variant is very small, there could be observed an excellent reflection in the copper demand under the simulated distribution as shown in Figure S2.

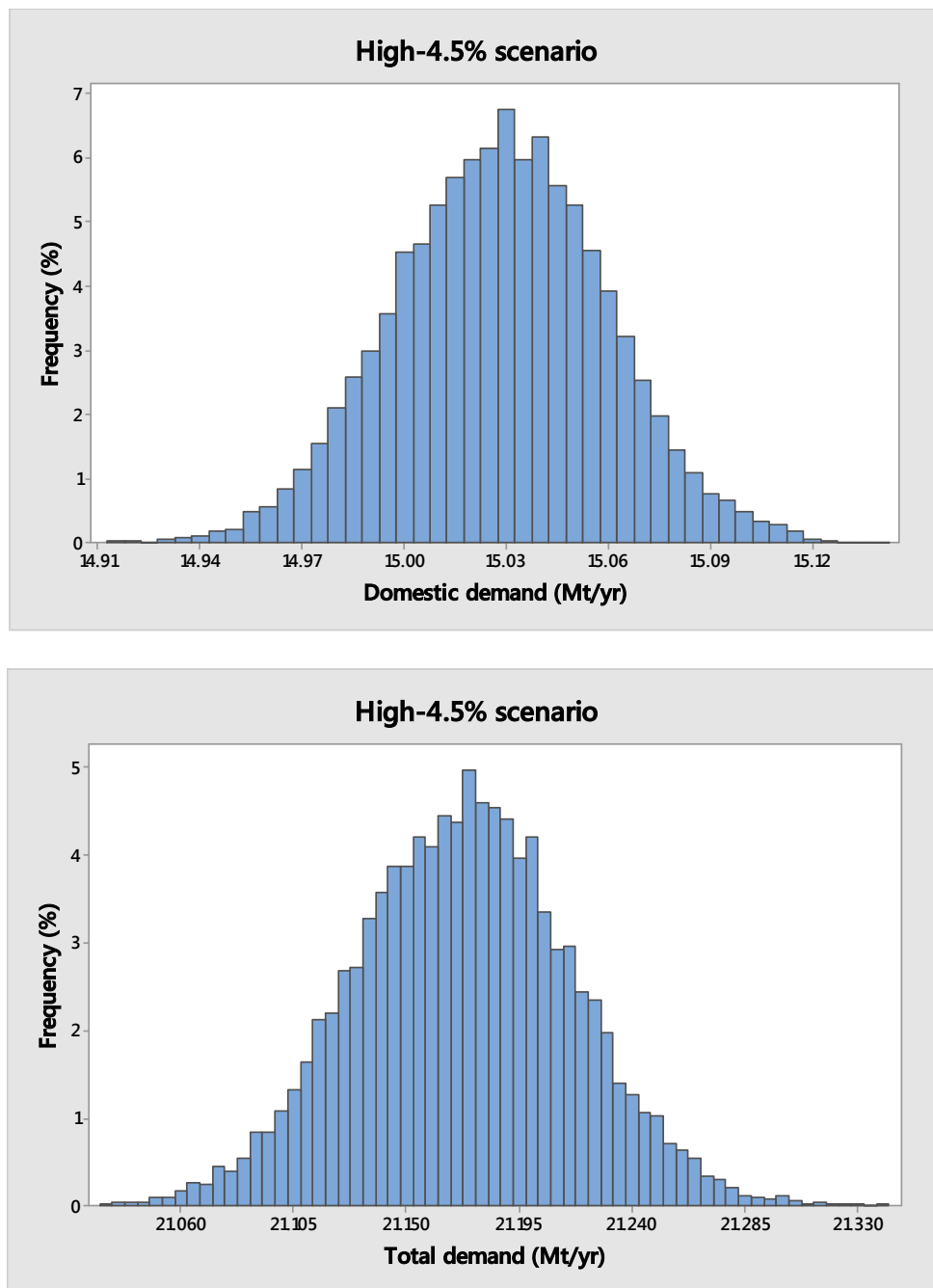


Figure S2. The aggregated uncertainties of copper demand under high-4.5% scenario from 2030 to 2050.

Table S6. The life span assumptions for end-use groups in China.

End-use group	Short life span in years	Medium life span in years	Long life span in years	References
Building & construction	20	30	40	(1), (14), (15)
Infrastructure	10	30	60	
Transportation	10	15	40	
Industrial & other equipment	10	15	30	

Table S7. Calculations of W_x^n projection (Unit: Mt).

Year	Linear regression	Population Vs Demand growth dynamics			
	y =8.1939x-16395 R ² =0.9572	Stable demand growth scenario	2.5% demand growth scenario	3.5% demand growth scenario	4.5% demand growth scenario
2016	1.24	1.20	1.23	1.24	1.25
2017	1.32	1.20	1.26	1.29	1.31
2018	1.40	1.21	1.30	1.34	1.38
2019	1.48	1.21	1.34	1.39	1.45
2020	1.57	1.21	1.37	1.44	1.51
2021	1.65	1.22	1.41	1.49	1.58
2022	1.73	1.22	1.45	1.55	1.66
2023	1.81	1.22	1.49	1.60	1.73
2024	1.89	1.22	1.52	1.66	1.81
2025	1.98	1.22	1.56	1.72	1.90
2026	2.06	1.22	1.60	1.78	1.98
2027	2.14	1.22	1.64	1.85	2.07
2028	2.22	1.22	1.68	1.91	2.16
2029	2.30	1.22	1.73	1.98	2.26
2030	2.39	1.22	1.77	2.04	2.36
2031	2.47	1.22	1.76	2.04	2.36
2032	2.55	1.22	1.76	2.04	2.35
2033	2.63	1.21	1.76	2.03	2.35
2034	2.71	1.21	1.75	2.03	2.34
2035	2.80	1.21	1.75	2.03	2.34
2036	2.88	1.21	1.75	2.03	2.34
2037	2.96	1.21	1.75	2.03	2.34
2038	3.04	1.21	1.75	2.03	2.34
2039	3.12	1.21	1.75	2.03	2.34
2040	3.21	1.20	1.74	2.02	2.33
2041	3.29	1.20	1.74	2.01	2.32
2042	3.37	1.19	1.73	2.00	2.31
2043	3.45	1.19	1.72	1.99	2.30

2044	3.53	1.18	1.71	1.98	2.29
2045	3.62	1.18	1.71	1.97	2.28
2046	3.70	1.18	1.71	1.97	2.28
2047	3.78	1.18	1.71	1.97	2.28
2048	3.86	1.18	1.71	1.97	2.28
2049	3.94	1.18	1.71	1.97	2.28
2050	4.02	1.17	1.70	1.96	2.27

Table S8. Overseas copper reserve acquisition from 1999 to 2018 by Chinese companies.¹⁶

Country	Reserves (tons)	Production in 2016 (tons)
Peru	4,947,000	-
Australia	13,000	1,900
Congo	577,000	80,700
Peru	7,710,000	330,200
Australia	1,211,700	36,700
Congo	4,718,100	202,100
Ecuador	20,000,000	-
Peru	3,150,000	-
Congo	1,540,000	-
Congo	24,160,000	-
Congo	202,000	42,300
Zambia	60,000	
Congo	293,000	
Congo	873,000	
Congo	1,777,000	
Zambia	800,000	26,000
Zambia	2,570,000	9,000
Afghanistan	10,000,000	-
Pakistan	223,700	13,100
Peru	6,830,000	150,000
Laos	25,300,000	78,500
Total	116,955,500	970,500

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