

# Risk Assessment of Water Resources-Energy Security Based on Cloud Model: A Case Study of China in 2020

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**Table S1.** Information flow value of risk factors and water shortage risk.

Criterion Layer	Indicator Layer	Information Flow
Water resources endowment	Water production modulus ( $10^4 \text{ m}^3/\text{km}^2$ )	0.0069
	Precipitation (mm)	0.1596
	Water resources per capita ( $\text{m}^3$ )	0.1068
	Surface water resources amount ( $10^8 \text{ m}^3$ )	0.1658
	Groundwater resources amount ( $10^8 \text{ m}^3$ )	0.1656
	Incoming water volume ( $10^8 \text{ m}^3$ )	0.0915
	GDP ( $10^8 \text{ yuan}$ )	0.0003
Social economy	GDP Per capita (yuan)	0.0035
	Proportion of primary industry (%)	0.0789
	Proportion of secondary industry (%)	0.0321
	Proportion of tertiary industry (%)	0.0389
	Water consumption Per 10,000-yuan GDP ( $\text{m}^3$ )	0.3341
	Population density ( $\text{per}/\text{km}^2$ )	0.005
	Natural growth rate of population (%)	0.0971
Water resources utilization	Urbanization rate (%)	0.0367
	Water supply per capita ( $\text{m}^3$ )	0.162
	Industrial water consumption ( $10^8 \text{ m}^3$ )	0.0236
	Agricultural water consumption ( $10^8 \text{ m}^3$ )	0.0159
	Domestic water consumption ( $10^8 \text{ m}^3$ )	0.0268
	Effective utilization coefficient of agricultural land irrigation water	0.0072
	Percentage of forest cover (%)	0.069
Water environment	Water consumption of ecological environment ( $10^8 \text{ m}^3$ )	0.0856
	discharge of wastewater ( $10^4 \times \text{m}^3$ )	0.0781
	Wastewater treatment rate (%)	0.0141

**Table S2.** Information flow value of risk factors and energy security risks.

Criterion Layer	Indicator Layer	Information Flow
Energy endowment	Elasticity coefficient of energy production	0.0012
	Energy reserve ratio	0.1271
	elasticity coefficient of electricity production	0.0022
	Power generation	0.0282

Social economy	Energy production per Capita (kg ce / per)	0.0564
	Energy import (10,000 tce)	0.1368
	Inventory increase and decrease (10 <sup>4</sup> tcel)	0.0553
	Degree of external dependence	0.1803
	GDP (100 million yuan)	0.0487
	GDP Per capita (yuan)	0.0496
	Proportion of primary industry	0.1695
	Proportion of secondary industry	0.3689
	Proportion of tertiary industry	0.1299
	Energy consumption per 10000-yuan GDP (tcel)	0.2026
Energy utilization	Population density (10 <sup>4</sup> people)	0.3412
	Natural population growth rate	0.0008
	Urbanization rate (%)	0.1889
	Elasticity coefficient of energy consumption	0.0012
	Elasticity coefficient of electricity consumption	0.0030
Atmospheric environment	Energy consumption per capita (kg ce)	0.0561
	Domestic energy per capita (kg ce)	0.0536
	Traffic route length (10 <sup>4</sup> km)	0.0268
	Vehicle ownership (10 <sup>4</sup> )	0.1693
	Conversion efficiency of energy processing	0.0093
	SO <sub>2</sub> emission reduction rate (%)	0.0009
	CO <sub>2</sub> emission per capita (10 <sup>4</sup> tons)	0.0107
	Emission of smoke (powder) dust (10 <sup>4</sup> tons)	0.0264
Total investment in environmental pollution control (10 <sup>8</sup> yuan)		0.0830

Table S3. Ranking results based on expert opinions.

	Precipitation	Precipitation Coefficient	Water Supply Per Capita	GDP Water Consumption Per 10,000 Yuan
Expert 1	1	2	3	4
Expert 2	2	1	3	4
Expert 3	1	3	2	4
Expert 4	2	1	3	4
Expert 5	3	2	1	4

Table S4. Calculation table of structure entropy weight of energy security risk assessment Indicator.

	Proportion Of Secondary Industry	Population Density	Energy Reserve Ratio	Energy Consumption Per 10,000 Yuan GDP
Expert 1	2	3	1	4
Expert 2	3	2	1	4
Expert 3	2	4	1	3
Expert 4	2	3	1	4
Expert 5	1	3	2	4
$b_j$	0.85	0.67	0.97	0.48
$Q_j$	0.02	0.05	0.08	0.15
$x_j$	0.83	0.64	0.89	0.41
W	0.300	0.231	0.321	0.148

Table S5. Assessment results of risk degree of water resources shortage with different guarantee rates.

P = 25%					Result	P = 50%					Result
U (1)	U (2)	U (3)	U (4)	U (5)		U (1)	U (2)	U (3)	U (4)	U (5)	

Beijing	0.0921	0.0256	0.2871	0.3902	0.1032	IV	0.0921	0.0196	0.1924	0.4287	0.1595	IV
Tianjin	0.1012	0.0166	0.2842	0.3032	0.1598	IV	0.1012	0.0166	0.1362	0.3269	0.1894	IV
Shanghai	0.2593	0.1087	0.2006	0.1063	0	I	0.2168	0.1087	0.2006	0.1537	0	I
Chongqing	0.3570	0.0982	0.0002	0.2502	0.0051	I	0.3067	0.1011	0.0002	0.2523	0.0051	I
Hebei	0	0.1178	0.1763	0.3506	0.2167	IV	0	0.1178	0.0756	0.4335	0.2463	IV
Shanxi	0	0.0544	0.1603	0.3844	0.2015	IV	0	0.0544	0.0508	0.4909	0.2134	IV
Liaoning	0.0059	0.3800	0.3101	0.5445	0.0077	IV	0	0.1639	0.3397	0.5534	0.0166	IV
Jilin	0.0030	0.1526	0.7724	0.3448	0.0089	III	0.0012	0.1022	0.7428	0.4188	0.0012	III
Hei-longjiang	0.1109	0.1273	0.3641	0.5074	0.0030	IV	0.1085	0.0651	0.2427	0.6139	0.0089	IV
Jiangsu	0.0525	0.3122	0.0362	0.1924	0	II	0.0229	0.4365	0.1842	0.2664	0	II
Zhejiang	0.6011	0.1238	0.0030	0.2570	0.0026	I	0.5803	0.1238	0.0030	0.2582	0.0026	I
Anhui	0.1569	0.0212	0.3297	0.0469	0	III	0.0740	0.0212	0.3297	0.1179	0	III
Fujian	0.5890	0.1087	0.1735	0.1002	0	I	0.5535	0.1087	0.1735	0.1020	0	I
Jiangxi	0.5890	0.0771	0.2032	0.0056	0	I	0.5328	0.0771	0.2032	0.0074	0	I
Shandong	0.0272	0.1806	0.0918	0.4234	0.0490	IV	0.0272	0.0918	0.2546	0.3731	0.0845	IV
Henan	0.0047	0.4172	0.0297	0.5103	0.0221	IV	0	0.2129	0.1273	0.4215	0.0458	IV
Hubei	0.2013	0.0415	0.2607	0.0332	0	III	0.1302	0.0445	0.2607	0.0657	0	III
Hunan	0.5417	0.0056	0.3492	0.0574	0	I	0.4410	0.0056	0.3492	0.0589	0	I
Guangdong	0.5846	0.1465	0.0339	0.2119	0.0003	I	0.5787	0.1465	0.0339	0.2128	0.0003	I
Hainan	0.5831	0.0020	0.3545	0.0654	0	I	0.5624	0.0020	0.3545	0.0660	0	I
Sichuan	0.2350	0.0967	0.0689	0.2225	0.0005	I	0.2723	0.3157	0.0718	0.2257	0.0005	II
Guizhou	0.2279	0.1374	0.0056	0.2663	0.0026	IV	0.2131	0.1433	0.0056	0.2633	0.0026	IV
Yunnan	0.1569	0.0106	0.0761	0.2929	0.0026	IV	0.1362	0.0106	0.0761	0.3048	0.0026	IV
Shaanxi	0.0089	0.3729	0.1880	0.5188	0.0132	IV	0.0036	0.1953	0.4929	0.5603	0.0162	IV
Gansu	0	0	0.1823	0.5606	0.0740	IV	0	0	0.1823	0.4837	0.1006	IV
Qinghai	0.0089	0.0512	0.1623	0.7026	0.0089	IV	0	0.0600	0.2038	0.7351	0.0089	IV
NeiMonggol	0.0051	0.2110	0.1450	0.2932	0.1806	IV	0.0051	0.2110	0.1450	0.2547	0.2279	IV
Guangxi	0.3552	0.1054	0.0975	0.0560	0	I	0.3256	0.1054	0.0975	0.0679	0	I
Xizang	0.3063	0.0643	0.1899	0.1411	0	I	0.3063	0.0643	0.0626	0.2358	0	I
Ningxia	0.0308	0	0.0003	0.3232	0.2842	IV	0.0308	0	0.0003	0.2522	0.2842	V
Xinjiang	0.2629	0.2102	0.1421	0.3582	0.1158	IV	0.2659	0.1450	0.0858	0.3049	0.1336	IV

	P = 75%					Result	P = 95%					Result
	U (1)	U (2)	U (3)	U (4)	U (5)		U (1)	U (2)	U (3)	U (4)	U (5)	
Beijing	0.0921	0.0196	0.0296	0.5619	0.1861	IV	0.0921	0.0196	0	0.5796	0.1772	IV
Tianjin	0.1012	0.0166	0.0385	0.3595	0.2782	IV	0.1012	0.0166	0.0030	0.3832	0.3670	IV
Shanghai	0.0521	0.2390	0.2006	0.2158	0	II	0.0284	0.4758	0.2450	0.2662	0	II
Chongqing	0.2775	0.1366	0.0002	0.2489	0.0051	I	0.1705	0.3498	0.0002	0.2514	0.0051	II
Hebei	0	0.1178	0.0342	0.4927	0.2581	IV	0	0.1178	0.0164	0.5282	0.2818	IV
Shanxi	0	0.0544	0.0301	0.5324	0.2370	IV	0	0.0544	0.0242	0.4258	0.3170	IV
Liaoning	0	0.1314	0.2450	0.5475	0.0521	IV	0	0.1314	0.0703	0.5919	0.0462	IV
Jilin	0.0015	0.0815	0.5918	0.5224	0	III	0.0089	0.0578	0.4438	0.5224	0.0030	IV
Hei-longjiang	0.1085	0.0089	0.0681	0.6790	0.0089	IV	0.1079	0	0.0059	0.6790	0.0326	IV
Jiangsu	0.0114	0.5224	0.0599	0.2960	0.0148	IV	0.0081	0.5135	0.0540	0.2131	0.0178	II
Zhejiang	0.4531	0.1238	0.0030	0.2570	0.0026	I	0.2991	0.1238	0.0030	0.2659	0.0026	I
Anhui	0.0444	0.1100	0.4600	0.1564	0	III	0.0207	0.3586	0.3504	0.1712	0	II
Fujian	0.4144	0.1087	0.1735	0.1002	0	I	0.1924	0.1087	0.1735	0.1121	0	I
Jiangxi	0.3552	0.0771	0.2032	0.0056	0	I	0.1598	0.0771	0.2032	0.0796	0	III
Shandong	0.0272	0.0770	0.2723	0.3701	0.0993	IV	0.0272	0.0770	0.0562	0.4323	0.2177	IV
Henan	0	0.1478	0.2842	0.3919	0.0724	IV	0	0.1389	0.2191	0.4097	0.1524	IV

Hubei	0.0503	0.0889	0.2607	0.1101	0	III	0.0207	0.3642	0.2696	0.1901	0	II
Hunan	0.3445	0.0056	0.3392	0.0565	0	I	0.2664	0.0086	0.3492	0.0684	0	III
Guangdong	0.5077	0.1465	0.0339	0.2107	0.0003	I	0.3064	0.1465	0.0339	0.2285	0.0003	I
Hainan	0.4588	0.0020	0.3545	0.0643	0	I	0.1717	0.0198	0.3545	0.0761	0	III
Sichuan	0.2960	0.1411	0.1458	0.2266	0.0005	III	0.2960	0.0227	0.3323	0.2946	0.0005	III
Guizhou	0.1480	0.2173	0.0056	0.2752	0.0026	IV	0.1154	0.4275	0.0115	0.2752	0.0026	II
Yunnan	0.0681	0.0195	0.0761	0.3136	0.0026	IV	0.0414	0.2000	0.0761	0.3373	0.0026	IV
Shaanxi	0.0033	0.1716	0.2768	0.6639	0.0192	IV	0.0039	0.2338	0.1288	0.8059	0.0162	IV
Gansu	0	0	0.1823	0.4541	0.1006	IV	0	0	0.1823	0.4126	0.1510	IV
Qinghai	0	0.0748	0.2245	0.7144	0.0266	IV	0.0030	0.1903	0.2689	0.6523	0.0296	IV
NeiMonggol	0.0051	0.2110	0.1450	0.1837	0.2338	V	0.0051	0.2110	0.1450	0.1866	0.2605	V
Guangxi	0.2250	0.1054	0.0975	0.0501	0	I	0.1273	0.1054	0.0975	0.0442	0	I
Xizang	0.3093	0.0643	0.0123	0.3028	0	I	0.3063	0.0643	0.0005	0.2891	0.0118	I
Ningxia	0.0308	0	0.0003	0.2048	0.3049	V	0.0308	0	0.0003	0.1427	0.3552	V
Xinjiang	0.2600	0.0651	0.1391	0.3197	0.1543	IV	0.2629	0.2190	0.2013	0.3078	0.1750	IV

Table S6. Assessment results of energy security risk degree.

Regions	<i>U</i> (1)	<i>U</i> (2)	<i>U</i> (3)	<i>U</i> (4)	<i>U</i> (5)	Result
Beijing	0.3000	0	0	0	0.5520	V
Tianjin	0.0030	0	0.3062	0	0.2310	III
Shanghai	0.0839	0	0	0	0.5520	V
Chongqing	0.0030	0.3454	0	0.0770	0	II
Hebei	0	0	0.0493	0.0013	0.1540	V
Shanxi	0.4457	0	0.0150	0	0.1480	I
Liaoning	0.3531	0	0	0	0.1288	I
Jilin	0.2310	0.0770	0.3000	0.0161	0	I
Heilongjiang	0.2850	0.1477	0	0	0.1480	I
Jiangsu	0.0252	0	0.0930	0	0.4974	V
Zhejiang	0	0.1480	0.2820	0	0.5520	V
Anhui	0.0030	0.3146	0.0060	0.0370	0	II
Fujian	0.0129	0	0.1980	0	0.2022	V
Jiangxi	0.0462	0	0.3086	0.0032	0.0225	III
Shandong	0.3210	0	0.3000	0.0104	0.2310	I
Henan	0	0.0840	0.1022	0	0.2310	V
Hubei	0.0137	0.0210	0	0	0.3210	V
Hunan	0.0129	0.1890	0	0.0032	0.0225	II
Guangdong	0.0163	0.0360	0.0835	0	0.2310	V
Hainan	0.3462	0.1480	0	0	0.1605	I
Sichuan	0.2440	0.0060	0.2340	0.0355	0	I
Guizhou	0.5220	0.1860	0	0	0.1480	I
Yunnan	0.2340	0.0360	0	0.1412	0.0089	I
Shaanxi	0.5474	0	0	0.0873	0.0120	I
Gansu	0.2880	0	0	0.2921	0.1480	IV
Qinghai	0.2310	0.0030	0	0.2119	0.2315	V
NeiMonggol	0.5520	0	0	0	0.1630	I
Guangxi	0.1894	0.0992	0.2490	0	0.3210	V
Ningxia	0.2310	0	0.1003	0	0.1480	I
Xinjiang	0.5820	0	0	0	0	I

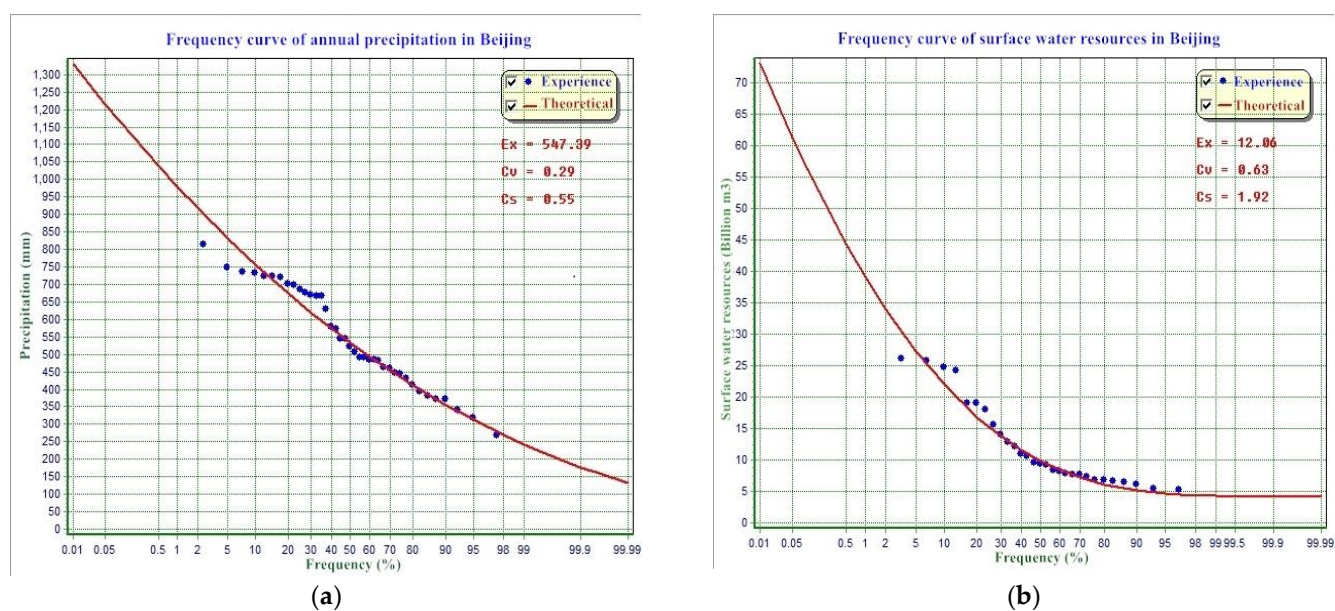


Figure S1. Frequency curve for (a) annual precipitation in Beijing; (b) surface water resources in Beijing

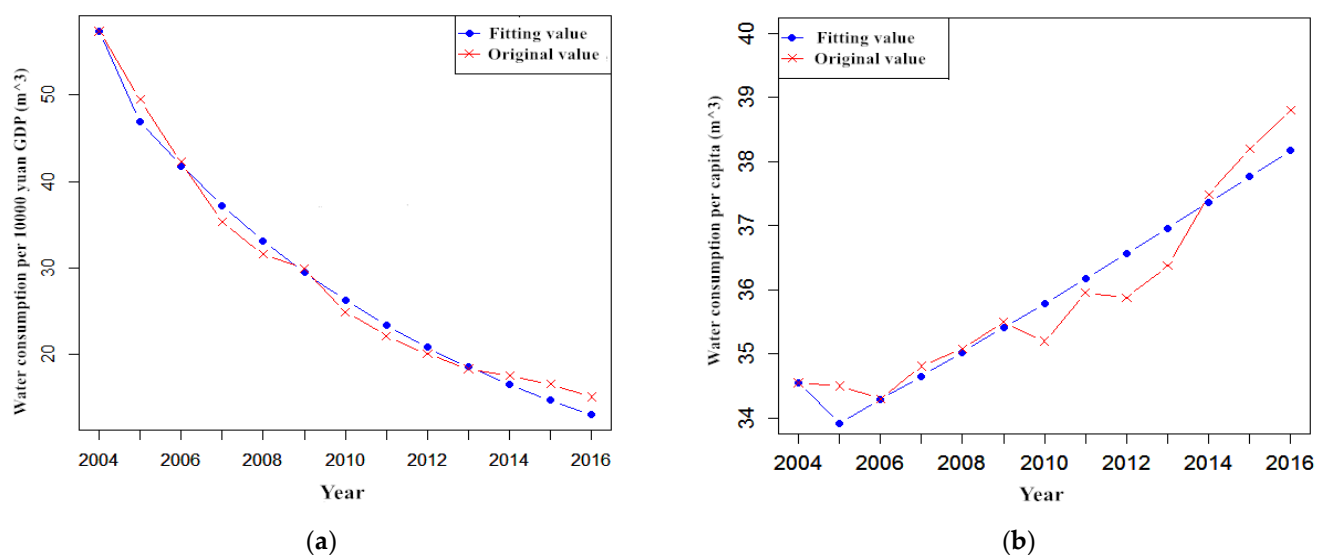


Figure S2. Comparison between the original value and the fitted value for (a) Water consumption per 10000-yuan GDP; (b) Water consumption per capita

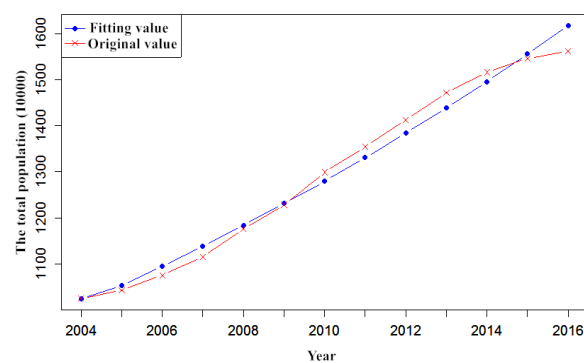
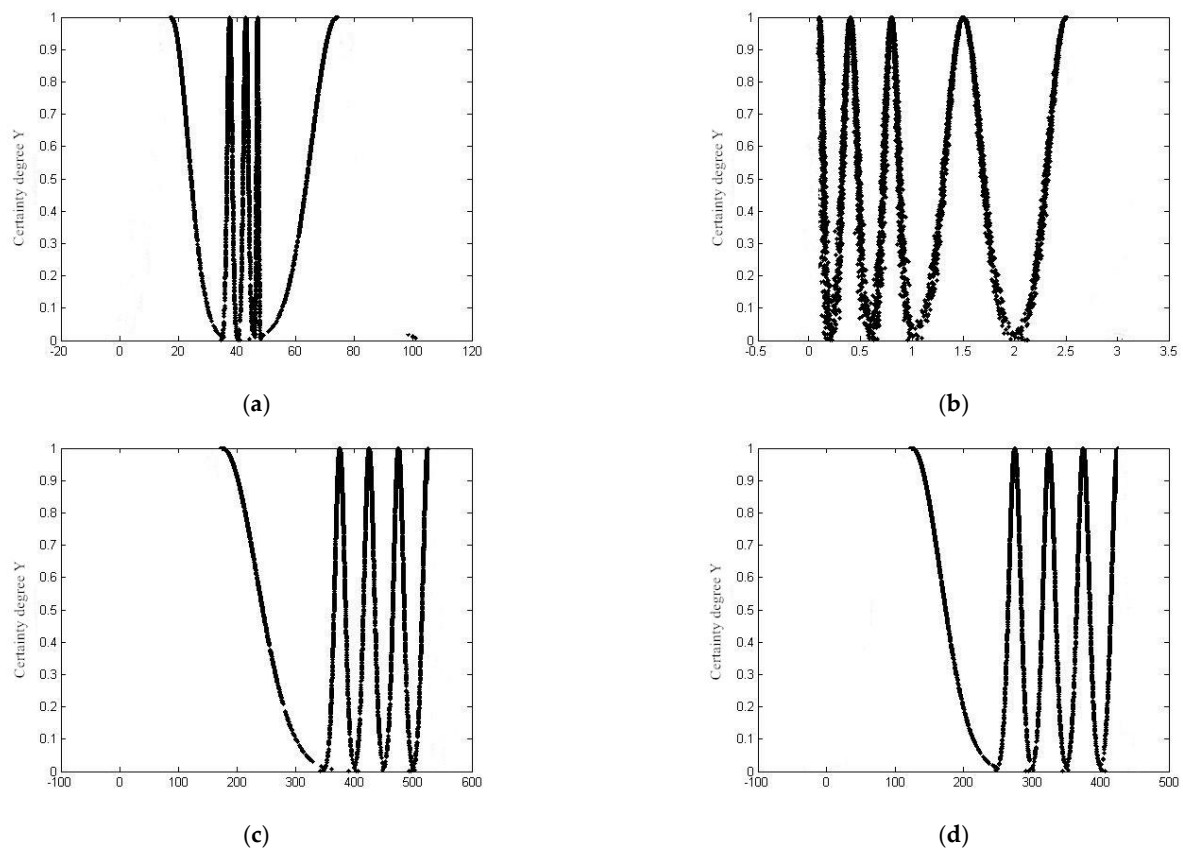


Figure S3. Comparison of the original and fitted values for population in Tianjin.



**Figure S4.** Cloud model of energy security belonging to risk level for (a) Proportion of secondary industry (on X-axis); (b) Energy reserve rate (on X-axis); (c) Energy consumption per 10000-yuan GDP (on X-axis); (d) Population density (on X-axis).