Supplementary Material


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Original Article

Long-term exposure to ambient NO_2 and adult mortality: A nationwide cohort study in China

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Section 1 Supplementary Methods & Data Source

1.1 *Supplementary descriptions for the CFPS interview and participants*

I. Reliability and validity of CFPS interview

In CFPS surveys, face-to-face interviews were performed by well-trained investigators, aided by computer-assisted personal interviewing technology. For those participants who were unable to respond themselves, a family member was asked to take his/her place to reply to the questionnaire items. During all stages of data collection, the CFPS research team adopted telephone check, field check, audio record check, interview reviews and statistical analyses to ensure data quality.

Besides, to assure the reliability and validity of the interview, the pilot investigations (baseline in 2008, and follow-up in 2009) had been conducted in three provincial regions (i.e., Beijing, Shanghai, and Guangdong) before the nationwide CFPS baseline survey in 2010. See details in prior publications for the CFPS survey.

II. Inclusion of CFPS participants

China Family Panel Studies is a nationally representative, annual longitudinal survey administered by the Institute of Social Science Survey (ISSS) of Peking University. CFPS baseline survey in 2010 totally includes 33,600 Chinese adult respondents residing in 162 counties or districts from 25 (of 30) provincial regions in China, wherein 94.5% of national population resided. All the sub-sampling frames of CFPS were based on a stratified three stage probability random sampling procedure: 1) the primary sampling unit: administrative districts/counties; 2) the second-stage sampling unit: administrative villages/communities; 3) the third-stage sampling unit: households. Family members aged 16 and above in each household in 2010 are selected as the CFPS baseline respondents and permanently included as follow-up subjects in subsequent waves of CFPS investigations. Finally, CFPS 2010 included a total of 33,600 participants enrolled from 14,608 households in 649 villages/communities.

1.2 *Supplementary methods for the calculation of attributable deaths*

Calculation formula of attributable death (AD):

$$AD_i = TD_i \times PAF_i = (Pop_i \times Mort_i) \times (\frac{HR_{C_i} - 1}{HR_{C_i}})$$

Where Pop_irefers to population size in county i, $Mort_i$ represents corresponding crude mortality rate, C_i denotes county-specific concentration of annual average NO_2, and HR_{C_i} indicates hazard ratio of all-cause mortality at concentration C_i.

County-specific population sizes in China for years 2010 and 2018 were aggregated from gridded population estimates at a 1×1-km resolution released by WorldPop (www.worldpop.org, accessed on November 30th, 2021). Given that we have only access to year-specific death rates by province from China Statistical Yearbook (http://www.stats.gov.cn/tjsj/ndsj/, accessed on November 30th, 2021) owing to data

availability, we thus assumed that crude mortality rates did not vary across counties in a provincial region. **Table A1** summarized provincial population estimates in China for years 2010 and 2018, aggregated from WorldPop's gridded datasets at a 1×1-km resolution. **Table A2** tabulated provincial estimates of crude death rates in China for years 2010 and 2018, derived from China Statistical Yearbook.

References

1. Xie, Y., Hu, J. W., An Introduction to the China Family Panel Studies (CFPS). Chin Sociol Rev 2014, 47, 3-29.
2. Xie, Y., Lu, P., The Sampling Design of the China Family Panel Studies (CFPS). Chin J Sociol 2015, 1, 471-484.
3. Yue, H.; He, C.; Huang, Q.; Yin, D.; Bryan, B. A., Stronger policy required to substantially reduce deaths from $PM_{2.5}$ pollution in China. Nat Commun 2020, 11, (1), 1462.
4. Li, T.; Zhang, Y.; Wang, J.; Xu, D.; Yin, Z.; Chen, H.; Lv, Y.; Luo, J.; Zeng, Y.; Liu, Y.; Kinney, P. L.; Shi, X., All-cause mortality risk associated with long-term exposure to ambient $PM_{2.5}$ in China: a cohort study. Lancet Public Health 2018, 3, (10), e470-e477.
5. Zhang, Y., All-Cause Mortality Risk and Attributable Deaths Associated with Long-Term Exposure to Ambient $PM_{2.5}$ in Chinese Adults. Environ Sci Technol 2021, 55, (9), 6116-6127.

Table A1 Provincial population estimates in China for years 2010 and 2018, aggregated from WorldPop's gridded datasets at a 1×1-km resolution

Region	Aggregated population ($\times 10^4$)	
	2010	**2018**
Beijing	2016	2648
Tianjin	1325	1611
Hebei	7375	7668
Shanxi	3674	3888
Mongolia	2562	2652
Liaoning	4486	4565
Jilin	2814	2811
Heilongjiang	3913	4018
Shanghai	2361	3031
Jiangsu	8075	8328
Zhejiang	5571	6250
Anhui	6107	6006
Fujian	3758	3989
Jiangxi	4580	4871
Shandong	9836	10135
Henan	9675	9761
Hubei	5880	5622
Hunan	6749	6819
Guangdong	10663	12197
Guangxi	4719	4807
Hainan	880	967
Chongqing	2964	2773
Sichuan	8264	8057
Guizhou	3572	3474
Yunnan	4710	4925
Tibet	308	338
Shaanxi	3829	3906
Gansu	2627	2613
Qinghai	578	647
Ningxia	648	722
Xinjiang	2242	2525

Table A2 Provincial estimates of crude death rates in China for years 2010 and 2018, derived from China Statistical Yearbook

Region	Crude death rate (‰)	
	2010	2018
National	7.11	7.13
Beijing	4.41	5.58
Tianjin	5.58	5.42
Hebei	6.41	6.36
Shanxi	5.38	5.32
Mongolia	5.54	5.95
Liaoning	6.26	7.39
Jilin	5.88	6.26
Heilongjiang	5.03	6.67
Shanghai	5.07	5.40
Jiangsu	6.88	7.03
Zhejiang	5.54	5.58
Anhui	5.95	5.96
Fujian	5.16	6.20
Jiangxi	6.06	6.06
Shandong	6.26	7.18
Henan	6.57	6.80
Hubei	6.02	7.00
Hunan	6.70	7.08
Guangdong	4.21	4.55
Guangxi	5.48	5.96
Hainan	5.73	6.01
Chongqing	6.40	7.54
Sichuan	6.62	7.01
Guizhou	6.55	6.85
Yunnan	6.56	6.32
Tibet	5.55	4.58
Shaanxi	6.01	6.24
Gansu	6.02	6.65
Qinghai	6.31	6.25
Ningxia	5.10	5.54
Xinjiang	5.43	4.56

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Table S1 AIC and BIC values of Cox models using 3–6 knots in RCS smoothing for annual average exposure to ambient NO_2

Number of knots	Model fit	
	AIC	BIC
n=3	17416.79	17531.91
n=4	17418.36	17538.71
n=5	17419.35	17544.93
n=6	17416.14	17546.96

Abbreviations: NO_2, nitrogen dioxide; AIC, Akaike information criterion; BIC, Bayesian information criterion; RCS, restricted cubic spline.

Table S2 Look-up table for exposure-response function of longitudinal association between annual exposure to ambient NO_2 and all-cause mortality in Chinese adults

NO_2 concentration	HR	95% LCL	95% UCL	NO_2 concentration	HR	95% LCL	95% UCL
6.9	1	1	1	32.5	1.498	1.156	1.941
7.0	1.002	1.000	1.004	32.6	1.499	1.157	1.942
7.1	1.005	1.001	1.009	32.7	1.499	1.157	1.942
7.2	1.007	1.001	1.013	32.8	1.500	1.158	1.943
7.3	1.009	1.001	1.017	32.9	1.501	1.159	1.943
7.4	1.011	1.001	1.022	33.0	1.501	1.159	1.944
7.5	1.014	1.002	1.026	33.1	1.502	1.160	1.944
7.6	1.016	1.002	1.030	33.2	1.503	1.161	1.945
7.7	1.018	1.002	1.035	33.3	1.503	1.162	1.945
7.8	1.021	1.002	1.039	33.4	1.504	1.162	1.946
7.9	1.023	1.003	1.044	33.5	1.505	1.163	1.946
8.0	1.025	1.003	1.048	33.6	1.505	1.164	1.947
8.1	1.028	1.003	1.053	33.7	1.506	1.164	1.948
8.2	1.030	1.004	1.057	33.8	1.506	1.165	1.948
8.3	1.032	1.004	1.062	33.9	1.507	1.166	1.949
8.4	1.035	1.004	1.066	34.0	1.508	1.166	1.950
8.5	1.037	1.004	1.071	34.1	1.508	1.167	1.950
8.6	1.040	1.005	1.076	34.2	1.509	1.167	1.951
8.7	1.042	1.005	1.080	34.3	1.510	1.168	1.952
8.8	1.044	1.005	1.085	34.4	1.510	1.168	1.952
8.9	1.047	1.005	1.090	34.5	1.511	1.169	1.953
9.0	1.049	1.006	1.094	34.6	1.512	1.170	1.954
9.1	1.051	1.006	1.099	34.7	1.512	1.170	1.955
9.2	1.054	1.006	1.104	34.8	1.513	1.171	1.956
9.3	1.056	1.007	1.108	34.9	1.514	1.171	1.957
9.4	1.059	1.007	1.113	35.0	1.514	1.172	1.957
9.5	1.061	1.007	1.118	35.1	1.515	1.172	1.958
9.6	1.064	1.007	1.123	35.2	1.516	1.173	1.959
9.7	1.066	1.008	1.128	35.3	1.516	1.173	1.960
9.8	1.068	1.008	1.132	35.4	1.517	1.174	1.961
9.9	1.071	1.008	1.137	35.5	1.518	1.174	1.962
10.0	1.073	1.008	1.142	35.6	1.518	1.175	1.963
10.1	1.076	1.009	1.147	35.7	1.519	1.175	1.964
10.2	1.078	1.009	1.152	35.8	1.520	1.175	1.965
10.3	1.081	1.009	1.157	35.9	1.520	1.176	1.966
10.4	1.083	1.010	1.162	36.0	1.521	1.176	1.967
10.5	1.086	1.010	1.167	36.1	1.522	1.177	1.968
10.6	1.088	1.010	1.172	36.2	1.522	1.177	1.969

10.7	1.091	1.010	1.177	36.3	1.523	1.177	1.970
10.8	1.093	1.011	1.182	36.4	1.524	1.178	1.971
10.9	1.096	1.011	1.187	36.5	1.524	1.178	1.972
11.0	1.098	1.011	1.192	36.6	1.525	1.178	1.974
11.1	1.101	1.011	1.197	36.7	1.526	1.179	1.975
11.2	1.103	1.012	1.203	36.8	1.526	1.179	1.976
11.3	1.106	1.012	1.208	36.9	1.527	1.179	1.977
11.4	1.108	1.012	1.213	37.0	1.528	1.180	1.978
11.5	1.111	1.013	1.218	37.1	1.528	1.180	1.980
11.6	1.113	1.013	1.223	37.2	1.529	1.180	1.981
11.7	1.116	1.013	1.229	37.3	1.530	1.180	1.982
11.8	1.118	1.013	1.234	37.4	1.530	1.181	1.984
11.9	1.121	1.014	1.239	37.5	1.531	1.181	1.985
12.0	1.123	1.014	1.245	37.6	1.532	1.181	1.986
12.1	1.126	1.014	1.250	37.7	1.532	1.181	1.988
12.2	1.128	1.014	1.255	37.8	1.533	1.182	1.989
12.3	1.131	1.015	1.261	37.9	1.534	1.182	1.990
12.4	1.134	1.015	1.266	38.0	1.534	1.182	1.992
12.5	1.136	1.015	1.272	38.1	1.535	1.182	1.993
12.6	1.139	1.016	1.277	38.2	1.536	1.182	1.995
12.7	1.141	1.016	1.283	38.3	1.536	1.182	1.996
12.8	1.144	1.016	1.288	38.4	1.537	1.183	1.998
12.9	1.147	1.016	1.294	38.5	1.538	1.183	1.999
13.0	1.149	1.017	1.299	38.6	1.538	1.183	2.001
13.1	1.152	1.017	1.305	38.7	1.539	1.183	2.002
13.2	1.155	1.017	1.310	38.8	1.540	1.183	2.004
13.3	1.157	1.017	1.316	38.9	1.540	1.183	2.006
13.4	1.160	1.018	1.322	39.0	1.541	1.183	2.007
13.5	1.162	1.018	1.327	39.1	1.542	1.183	2.009
13.6	1.165	1.018	1.333	39.2	1.542	1.183	2.010
13.7	1.168	1.019	1.339	39.3	1.543	1.183	2.012
13.8	1.170	1.019	1.344	39.4	1.544	1.183	2.014
13.9	1.173	1.019	1.350	39.5	1.544	1.183	2.016
14.0	1.176	1.019	1.356	39.6	1.545	1.183	2.017
14.1	1.178	1.020	1.362	39.7	1.546	1.183	2.019
14.2	1.181	1.020	1.368	39.8	1.546	1.183	2.021
14.3	1.184	1.020	1.374	39.9	1.547	1.183	2.023
14.4	1.186	1.021	1.379	40.0	1.548	1.183	2.024
14.5	1.189	1.021	1.385	40.1	1.548	1.183	2.026
14.6	1.192	1.021	1.391	40.2	1.549	1.183	2.028
14.7	1.195	1.021	1.397	40.3	1.550	1.183	2.030
14.8	1.197	1.022	1.403	40.4	1.551	1.183	2.032
14.9	1.200	1.022	1.409	40.5	1.551	1.183	2.034
15.0	1.203	1.022	1.415	40.6	1.552	1.183	2.035

15.1	1.205	1.023	1.421	40.7	1.553	1.183	2.037
15.2	1.208	1.023	1.427	40.8	1.553	1.183	2.039
15.3	1.211	1.023	1.433	40.9	1.554	1.183	2.041
15.4	1.214	1.023	1.439	41.0	1.555	1.183	2.043
15.5	1.216	1.024	1.445	41.1	1.555	1.183	2.045
15.6	1.219	1.024	1.451	41.2	1.556	1.182	2.047
15.7	1.222	1.024	1.457	41.3	1.557	1.182	2.049
15.8	1.224	1.025	1.463	41.4	1.557	1.182	2.051
15.9	1.227	1.025	1.469	41.5	1.558	1.182	2.053
16.0	1.230	1.025	1.475	41.6	1.559	1.182	2.056
16.1	1.233	1.026	1.481	41.7	1.559	1.182	2.058
16.2	1.235	1.026	1.487	41.8	1.560	1.182	2.060
16.3	1.238	1.026	1.493	41.9	1.561	1.181	2.062
16.4	1.241	1.027	1.499	42.0	1.561	1.181	2.064
16.5	1.243	1.027	1.505	42.1	1.562	1.181	2.066
16.6	1.246	1.027	1.511	42.2	1.563	1.181	2.068
16.7	1.249	1.028	1.517	42.3	1.563	1.180	2.071
16.8	1.251	1.028	1.523	42.4	1.564	1.180	2.073
16.9	1.254	1.028	1.529	42.5	1.565	1.180	2.075
17.0	1.257	1.029	1.535	42.6	1.565	1.180	2.077
17.1	1.259	1.029	1.541	42.7	1.566	1.179	2.080
17.2	1.262	1.030	1.547	42.8	1.567	1.179	2.082
17.3	1.265	1.030	1.553	42.9	1.568	1.179	2.084
17.4	1.267	1.030	1.559	43.0	1.568	1.179	2.086
17.5	1.270	1.031	1.565	43.1	1.569	1.178	2.089
17.6	1.273	1.031	1.571	43.2	1.570	1.178	2.091
17.7	1.275	1.031	1.577	43.3	1.570	1.178	2.094
17.8	1.278	1.032	1.583	43.4	1.571	1.177	2.096
17.9	1.281	1.032	1.589	43.5	1.572	1.177	2.098
18.0	1.283	1.033	1.595	43.6	1.572	1.177	2.101
18.1	1.286	1.033	1.601	43.7	1.573	1.176	2.103
18.2	1.289	1.034	1.606	43.8	1.574	1.176	2.106
18.3	1.291	1.034	1.612	43.9	1.574	1.176	2.108
18.4	1.294	1.034	1.618	44.0	1.575	1.175	2.111
18.5	1.296	1.035	1.624	44.1	1.576	1.175	2.113
18.6	1.299	1.035	1.629	44.2	1.576	1.175	2.116
18.7	1.301	1.036	1.635	44.3	1.577	1.174	2.118
18.8	1.304	1.036	1.641	44.4	1.578	1.174	2.121
18.9	1.307	1.037	1.646	44.5	1.578	1.173	2.123
19.0	1.309	1.037	1.652	44.6	1.579	1.173	2.126
19.1	1.312	1.038	1.658	44.7	1.580	1.173	2.129
19.2	1.314	1.038	1.663	44.8	1.581	1.172	2.131
19.3	1.317	1.039	1.669	44.9	1.581	1.172	2.134
19.4	1.319	1.039	1.674	45.0	1.582	1.171	2.136

19.5	1.322	1.040	1.680	45.1	1.583	1.171	2.139
19.6	1.324	1.040	1.685	45.2	1.583	1.170	2.142
19.7	1.326	1.041	1.690	45.3	1.584	1.170	2.145
19.8	1.329	1.041	1.696	45.4	1.585	1.170	2.147
19.9	1.331	1.042	1.701	45.5	1.585	1.169	2.150
20.0	1.334	1.043	1.706	45.6	1.586	1.169	2.153
20.1	1.336	1.043	1.711	45.7	1.587	1.168	2.155
20.2	1.338	1.044	1.716	45.8	1.587	1.168	2.158
20.3	1.341	1.044	1.721	45.9	1.588	1.167	2.161
20.4	1.343	1.045	1.726	46.0	1.589	1.167	2.164
20.5	1.345	1.046	1.731	46.1	1.590	1.166	2.167
20.6	1.348	1.046	1.736	46.2	1.590	1.166	2.169
20.7	1.350	1.047	1.741	46.3	1.591	1.165	2.172
20.8	1.352	1.047	1.746	46.4	1.592	1.165	2.175
20.9	1.355	1.048	1.751	46.5	1.592	1.164	2.178
21.0	1.357	1.049	1.755	46.6	1.593	1.164	2.181
21.1	1.359	1.049	1.760	46.7	1.594	1.163	2.184
21.2	1.361	1.050	1.764	46.8	1.594	1.162	2.187
21.3	1.363	1.051	1.769	46.9	1.595	1.162	2.190
21.4	1.365	1.051	1.773	47.0	1.596	1.161	2.193
21.5	1.368	1.052	1.778	47.1	1.596	1.161	2.196
21.6	1.370	1.053	1.782	47.2	1.597	1.160	2.199
21.7	1.372	1.054	1.786	47.3	1.598	1.160	2.202
21.8	1.374	1.054	1.790	47.4	1.599	1.159	2.205
21.9	1.376	1.055	1.794	47.5	1.599	1.159	2.208
22.0	1.378	1.056	1.798	47.6	1.600	1.158	2.211
22.1	1.380	1.057	1.802	47.7	1.601	1.157	2.214
22.2	1.382	1.057	1.806	47.8	1.601	1.157	2.217
22.3	1.384	1.058	1.810	47.9	1.602	1.156	2.220
22.4	1.386	1.059	1.813	48.0	1.603	1.156	2.223
22.5	1.388	1.060	1.817	48.1	1.603	1.155	2.226
22.6	1.390	1.061	1.820	48.2	1.604	1.154	2.229
22.7	1.391	1.061	1.824	48.3	1.605	1.154	2.233
22.8	1.393	1.062	1.827	48.4	1.606	1.153	2.236
22.9	1.395	1.063	1.831	48.5	1.606	1.152	2.239
23.0	1.397	1.064	1.834	48.6	1.607	1.152	2.242
23.1	1.399	1.065	1.837	48.7	1.608	1.151	2.245
23.2	1.400	1.066	1.840	48.8	1.608	1.150	2.248
23.3	1.402	1.067	1.843	48.9	1.609	1.150	2.252
23.4	1.404	1.068	1.846	49.0	1.610	1.149	2.255
23.5	1.406	1.068	1.849	49.1	1.610	1.149	2.258
23.6	1.407	1.069	1.852	49.2	1.611	1.148	2.262
23.7	1.409	1.070	1.855	49.3	1.612	1.147	2.265
23.8	1.411	1.071	1.857	49.4	1.613	1.147	2.268

23.9	1.412	1.072	1.860	49.5	1.613	1.146	2.271
24.0	1.414	1.073	1.863	49.6	1.614	1.145	2.275
24.1	1.415	1.074	1.865	49.7	1.615	1.144	2.278
24.2	1.417	1.075	1.868	49.8	1.615	1.144	2.281
24.3	1.418	1.076	1.870	49.9	1.616	1.143	2.285
24.4	1.420	1.077	1.872	50.0	1.617	1.142	2.288
24.5	1.421	1.078	1.875	50.1	1.618	1.142	2.292
24.6	1.423	1.079	1.877	50.2	1.618	1.141	2.295
24.7	1.424	1.080	1.879	50.3	1.619	1.140	2.298
24.8	1.426	1.081	1.881	50.4	1.620	1.140	2.302
24.9	1.427	1.082	1.883	50.5	1.620	1.139	2.305
25.0	1.429	1.083	1.885	50.6	1.621	1.138	2.309
25.1	1.430	1.084	1.887	50.7	1.622	1.137	2.312
25.2	1.431	1.085	1.889	50.8	1.622	1.137	2.316
25.3	1.433	1.086	1.891	50.9	1.623	1.136	2.319
25.4	1.434	1.087	1.893	51.0	1.624	1.135	2.323
25.5	1.435	1.088	1.894	51.1	1.625	1.135	2.326
25.6	1.437	1.089	1.896	51.2	1.625	1.134	2.330
25.7	1.438	1.090	1.898	51.3	1.626	1.133	2.333
25.8	1.439	1.091	1.899	51.4	1.627	1.132	2.337
25.9	1.441	1.092	1.901	51.5	1.627	1.132	2.341
26.0	1.442	1.093	1.902	51.6	1.628	1.131	2.344
26.1	1.443	1.094	1.904	51.7	1.629	1.130	2.348
26.2	1.444	1.095	1.905	51.8	1.630	1.129	2.351
26.3	1.445	1.096	1.906	51.9	1.630	1.129	2.355
26.4	1.447	1.097	1.908	52.0	1.631	1.128	2.359
26.5	1.448	1.098	1.909	52.1	1.632	1.127	2.362
26.6	1.449	1.099	1.910	52.2	1.632	1.126	2.366
26.7	1.450	1.100	1.911	52.3	1.633	1.125	2.370
26.8	1.451	1.101	1.912	52.4	1.634	1.125	2.374
26.9	1.452	1.102	1.914	52.5	1.635	1.124	2.377
27.0	1.453	1.103	1.915	52.6	1.635	1.123	2.381
27.1	1.454	1.104	1.916	52.7	1.636	1.122	2.385
27.2	1.455	1.105	1.917	52.8	1.637	1.122	2.388
27.3	1.457	1.106	1.918	52.9	1.637	1.121	2.392
27.4	1.458	1.107	1.918	53.0	1.638	1.120	2.396
27.5	1.459	1.108	1.919	53.1	1.639	1.119	2.400
27.6	1.460	1.109	1.920	53.2	1.640	1.118	2.404
27.7	1.461	1.111	1.921	53.3	1.640	1.118	2.407
27.8	1.462	1.112	1.922	53.4	1.641	1.117	2.411
27.9	1.463	1.113	1.923	53.5	1.642	1.116	2.415
28.0	1.463	1.114	1.923	53.6	1.642	1.115	2.419
28.1	1.464	1.115	1.924	53.7	1.643	1.114	2.423
28.2	1.465	1.116	1.925	53.8	1.644	1.113	2.427

28.3	1.466	1.117	1.925	53.9	1.645	1.113	2.431
28.4	1.467	1.118	1.926	54.0	1.645	1.112	2.435
28.5	1.468	1.119	1.926	54.1	1.646	1.111	2.439
28.6	1.469	1.120	1.927	54.2	1.647	1.110	2.442
28.7	1.470	1.121	1.928	54.3	1.647	1.109	2.446
28.8	1.471	1.122	1.928	54.4	1.648	1.109	2.450
28.9	1.472	1.123	1.929	54.5	1.649	1.108	2.454
29.0	1.472	1.124	1.929	54.6	1.650	1.107	2.458
29.1	1.473	1.125	1.929	54.7	1.650	1.106	2.462
29.2	1.474	1.126	1.930	54.8	1.651	1.105	2.466
29.3	1.475	1.127	1.930	54.9	1.652	1.104	2.470
29.4	1.476	1.128	1.931	55.0	1.652	1.104	2.474
29.5	1.477	1.129	1.931	55.1	1.653	1.103	2.478
29.6	1.477	1.130	1.932	55.2	1.654	1.102	2.483
29.7	1.478	1.131	1.932	55.3	1.655	1.101	2.487
29.8	1.479	1.132	1.932	55.4	1.655	1.100	2.491
29.9	1.480	1.133	1.933	55.5	1.656	1.099	2.495
30.0	1.481	1.134	1.933	55.6	1.657	1.098	2.499
30.1	1.481	1.135	1.933	55.7	1.658	1.098	2.503
30.2	1.482	1.136	1.934	55.8	1.658	1.097	2.507
30.3	1.483	1.137	1.934	55.9	1.659	1.096	2.511
30.4	1.484	1.138	1.934	56.0	1.660	1.095	2.516
30.5	1.484	1.139	1.935	56.1	1.660	1.094	2.520
30.6	1.485	1.140	1.935	56.2	1.661	1.093	2.524
30.7	1.486	1.141	1.935	56.3	1.662	1.092	2.528
30.8	1.486	1.141	1.936	56.4	1.663	1.092	2.532
30.9	1.487	1.142	1.936	56.5	1.663	1.091	2.537
31.0	1.488	1.143	1.936	56.6	1.664	1.090	2.541
31.1	1.489	1.144	1.937	56.7	1.665	1.089	2.545
31.2	1.489	1.145	1.937	56.8	1.665	1.088	2.549
31.3	1.490	1.146	1.937	56.9	1.666	1.087	2.554
31.4	1.491	1.147	1.937	57.0	1.667	1.086	2.558
31.5	1.491	1.148	1.938	57.1	1.668	1.085	2.562
31.6	1.492	1.149	1.938	57.2	1.668	1.085	2.566
31.7	1.493	1.149	1.938	57.3	1.669	1.084	2.571
31.8	1.493	1.150	1.939	57.4	1.670	1.083	2.575
31.9	1.494	1.151	1.939	57.5	1.671	1.082	2.580
32.0	1.495	1.152	1.939	57.6	1.671	1.081	2.584
32.1	1.495	1.153	1.940	57.7	1.672	1.080	2.588
32.2	1.496	1.153	1.940	57.8	1.673	1.079	2.593
32.3	1.497	1.154	1.941	57.9	1.674	1.078	2.597
32.4	1.497	1.155	1.941	58.0	1.674	1.078	2.601

Abbreviations: NO_2, nitrogen dioxide; HR, hazard ratio; LCL, lower confidence limit; UCL, upper confidence limit.

Table S3 Sensitive analyses of HR [95% CI] estimates for all-cause mortality associated with a-10 μg/m^3 increase in exposure to ambient NO_2

Analytic strategies	Adjusted covariates	HR [95% CI]	P for association
Main analysis	Stratified by age and sex, adjusted for ethnicity, BMI, education, marital status, employment, physical activity, smoking, drinking, sleep duration, household air pollution, income, prevalence of chronic diseases, depressive symptoms, and urbanicity	1.127 [1.042–1.219]	0.003
Sensitivity analyses			
Co-pollutant analysis + $PM_{2.5}$	Covariates adjusted in main analysis plus ambient $PM_{2.5}$	1.158 [1.043–1.286]	0.006
Co-pollutant analysis + O_3	Covariates adjusted in main analysis plus ambient O_3	1.144 [1.052–1.244]	0.002
Co-pollutant analysis + $PM_{2.5}$ + O_3	Covariates adjusted in main analysis plus ambient $PM_{2.5}$ and O_3	1.169 [1.051–1.301]	0.004
Temperature-adjusted analysis	Covariates adjusted in main analysis plus annual average temperature	1.121 [1.025–1.225]	0.012
*DAG-based analysis**	Stratified by age and sex, adjusted for education, income, and urbanicity	1.081 [1.007–1.159]	0.030

Abbreviations: HR, hazard ratio; CI, confidence interval; BMI, body-mass index; NO_2, nitrogen dioxide; $PM_{2.5}$, particulate matter with aerodynamic diameter ≤2.5 μm; O_3, ozone; DAG, directed acyclic graph. *Covariates in DAG-based analysis were minimal sufficient adjustment sets, which was determined by combining the evaluation of DAG-dataset consistency with the identification of valid adjustment sets for statistically equivalent DAGs. Please also refer to the website of online DAGitty tool (http://www.dagitty.net/learn/index.html, accessed on November 30th, 2021) for details.

Table S4 Provincial estimates of all-cause deaths and fractions attributable to ambient NO_2 in China for years 2010 and 2018, based on a counterfactual exposure of 6.9 μg/m^3

Region	NO_2-attributable deaths		Attributable fraction, %	
	2010	2018	2010	2018
Beijing	26501	39988	29.8	27.1
Tianjin	21826	22890	29.5	26.2
Hebei	126705	113626	26.8	23.3
Shanxi	48172	47015	24.4	22.7
Mongolia	21397	19723	15.1	12.5
Liaoning	61925	59098	22.1	17.5
Jilin	26970	16997	16.3	9.7
Heilongjiang	30911	26436	15.7	9.9
Shanghai	37014	47064	30.9	28.8
Jiangsu	148955	144731	26.8	24.7
Zhejiang	75625	70061	24.5	20.1
Anhui	81863	74352	22.5	20.8
Fujian	32388	34943	16.7	14.1
Jiangxi	40446	36837	14.6	12.5
Shandong	155423	148002	25.2	20.3
Henan	146965	133350	23.1	20.1
Hubei	79768	79874	22.5	20.3
Hunan	82632	67835	18.3	14.1
Guangdong	81282	93624	18.1	16.9
Guangxi	29770	29538	11.5	10.3
Hainan	2508	2969	5.0	5.1
Chongqing	45069	46213	23.8	22.1
Sichuan	125423	119651	22.9	21.2
Guizhou	37373	27943	16.0	11.7
Yunnan	32579	31448	10.5	10.1
Tibet	1627	570	9.5	3.7
Shaanxi	55377	55420	24.1	22.7
Gansu	28917	26787	18.3	15.4
Qinghai	6553	5867	18.0	14.5
Ningxia	5342	5806	16.2	14.5
Xinjiang	27575	22325	22.7	19.4

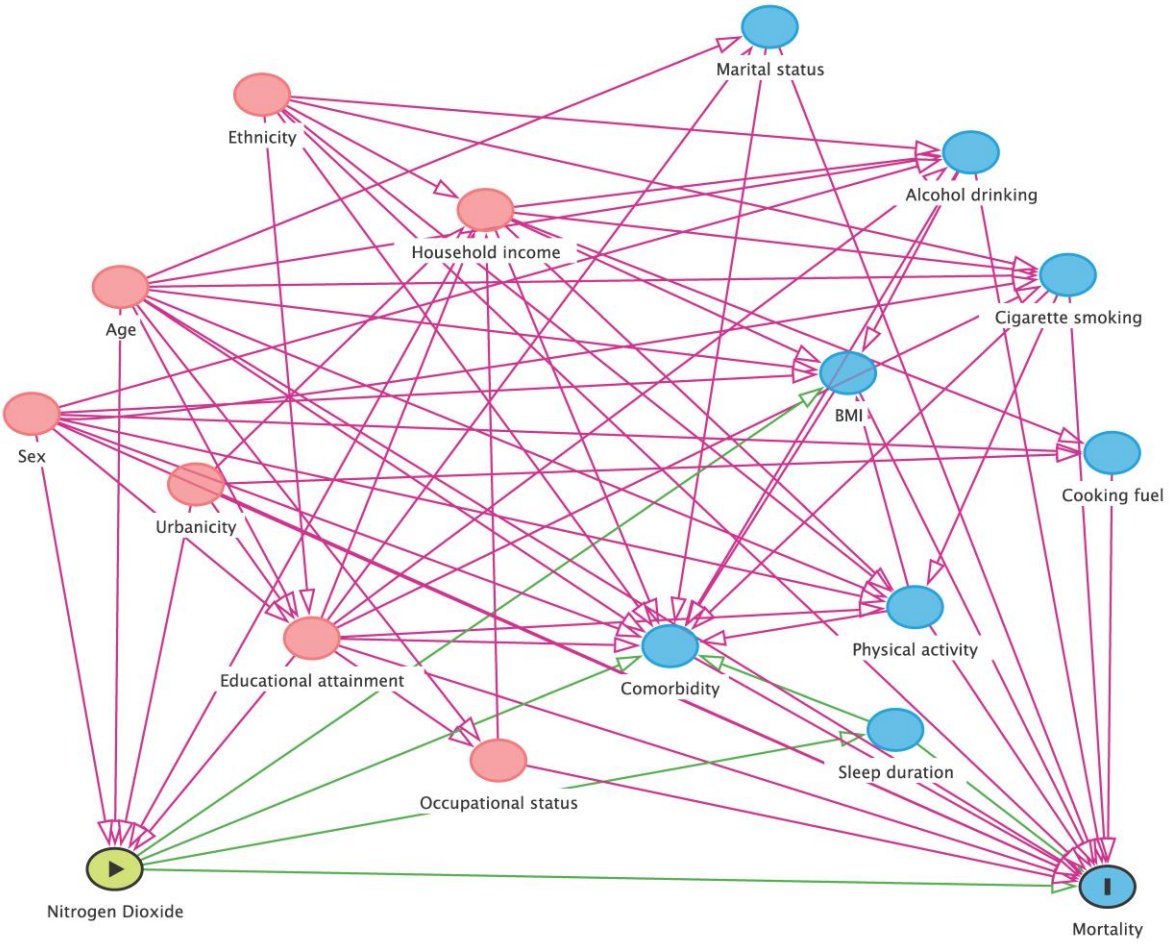

Fig. S1 Directed acyclic graph for the longitudinal association between ambient NO_2 exposure and adult mortality, created using the online DAGitty tool (www.dagitty.net, accessed on November 30th, 2021). The minimally sufficient adjustment set identified by DAG method included sex, age, education, urbanicity, and household income. BMI, body-mass index; NO_2, nitrogen dioxide; DAG, directed acyclic graph.

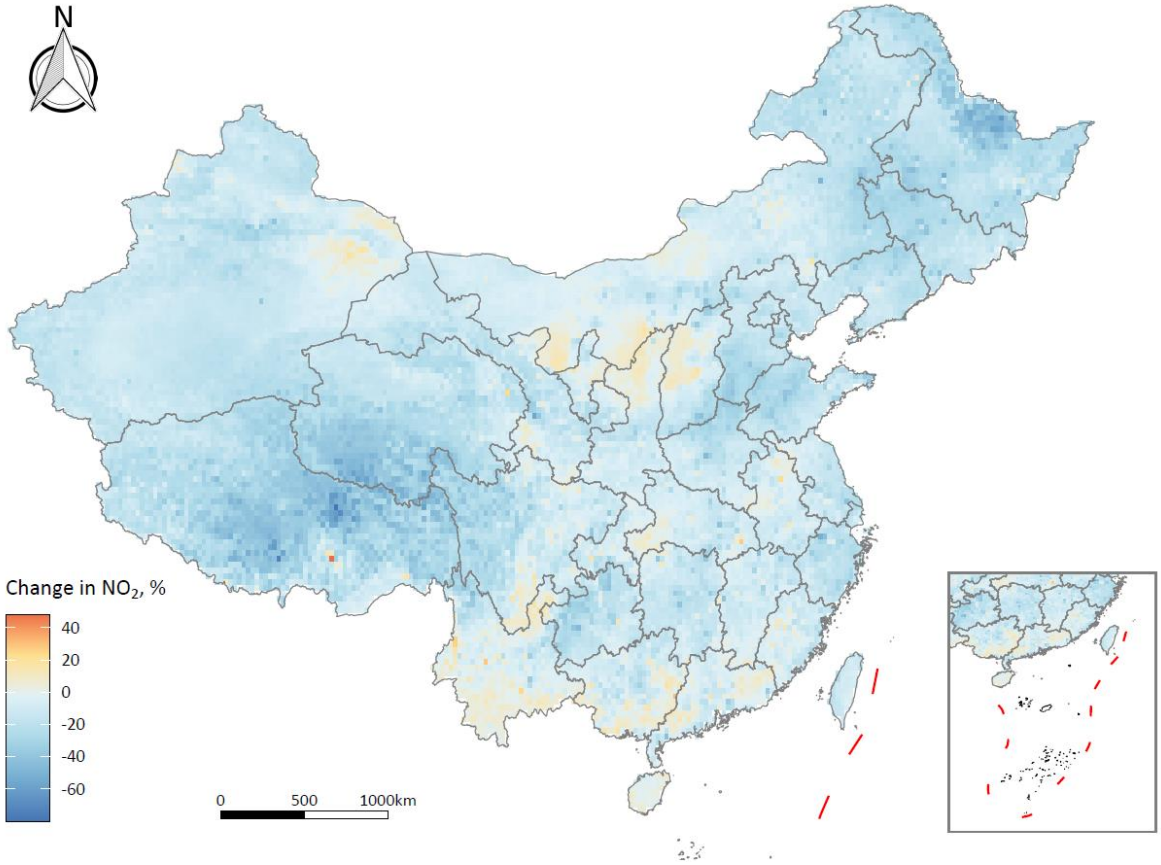

Fig. S2 Percentage change (%) of average NO_2 concentration between 2010 and 2018. Islands in the South China Sea are shown in the box. NO_2, nitrogen dioxide.

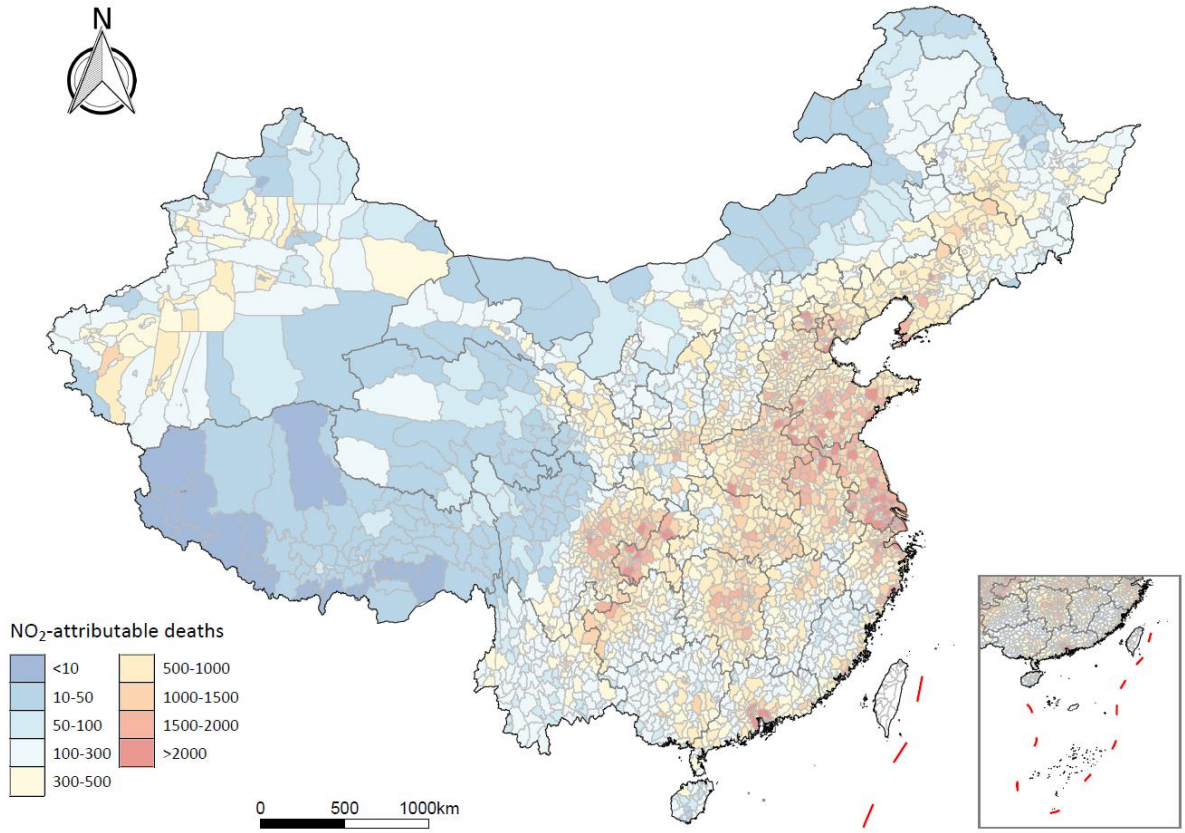

Fig. S3 County-specific estimates of all-cause deaths attributable to ambient NO_2 across China in 2010. Taiwan Province is not included for assessment and islands in the South China Sea are shown in the box. NO_2, nitrogen dioxide.

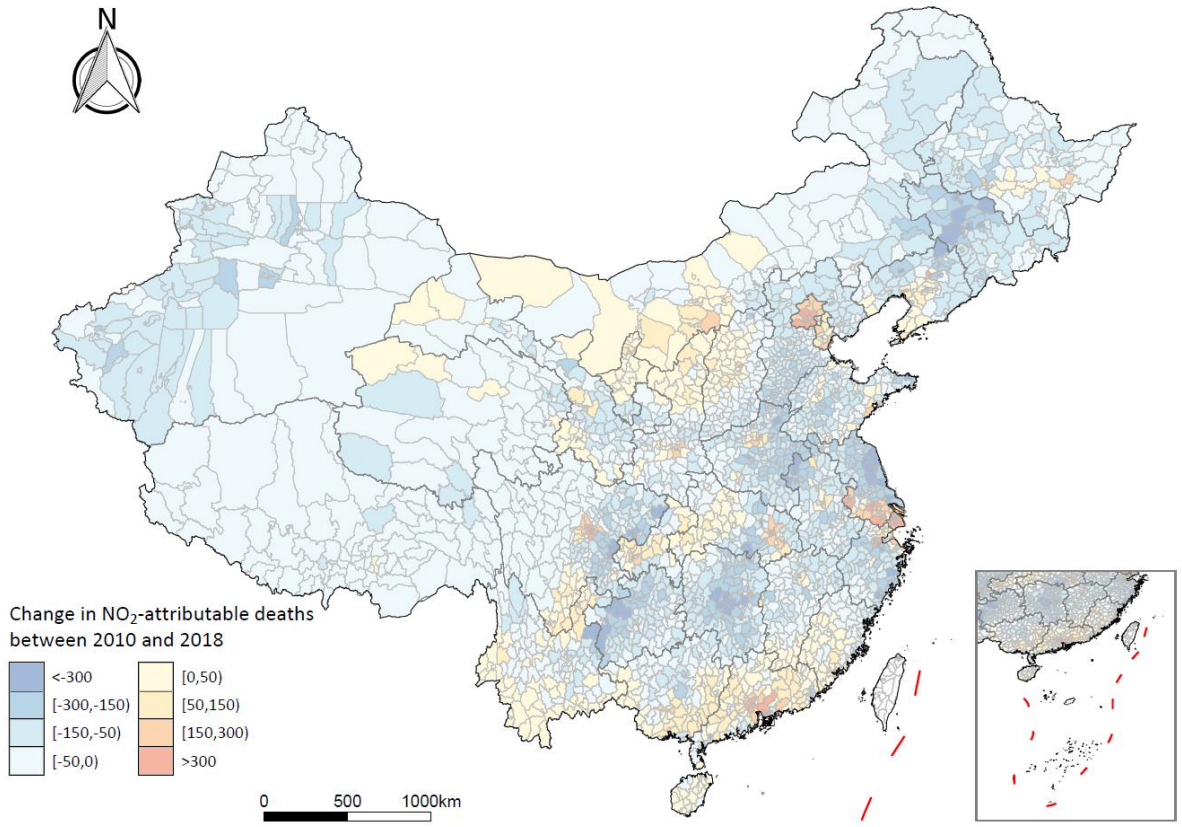

Fig. S4 Regional changes in estimates of NO_2-attributable deaths in China between 2010 and 2018. Taiwan Province is not included for assessment and islands in the South China Sea are shown in the box. NO_2, nitrogen dioxide.