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Supplemental Material

Mortality Risk and Fine Particulate Air Pollution in a Large, Representative Cohort of U.S. Adults

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Figure S1. Illustration of approach to estimate back-casted, imputed $\text{PM}_{2.5}$ from 1988-1998. Black circles indicate modeled annual mean $\text{PM}_{2.5}$ concentrations for the 17 years (1999–2015) with regulatory monitoring data for $\text{PM}_{2.5}$ estimated using the universal kriging modeling framework. Black squares indicate modeled annual mean PM_{10} concentrations for the 28 years (1988–2015) with regulatory monitoring data for PM_{10} also estimated using the universal kriging modeling framework. Grey circles indicate the back-casted, imputed $\text{PM}_{2.5}$ estimated from 1988-1998 based on modeled PM_{10} and census –tract mean $\text{PM}_{2.5}/\text{PM}_{10}$ ratios for 1999-2003. This back-casting approach was used for each census tract separately. For simple illustration, this figure presents averages across all census tracts (urban and rural) in the contiguous U.S. (average $\text{PM}_{2.5}/\text{PM}_{10}$ ratio for 1999-2003 was 0.58).

Table S1. Estimated hazard ratios (and 95% CIs) for all-cause, cardiopulmonary, and lung cancer mortality for key variables using the sub-cohort and the full complex CPH model.

	All Causes of Death		Cardiopulmonary ^a		Lung Cancer ^a	
	Hazard Ratio	95% CI	Hazard Ratio	95% CI	Hazard Ratio	95% CI
PM _{2.5} (x10 µg/m ³)	1.12	1.08-1.15	1.23	1.17-1.29	1.12	1.00-1.26
Income						
\$ 0-35,000	1.59	1.55-1.63	1.77	1.70-1.84	1.34	1.23-1.46
\$ 35-50,000	1.34	1.31-1.37	1.46	1.40-1.52	1.20	1.09-1.32
\$ 50-75,000	1.19	1.16-1.22	1.26	1.21-1.31	1.11	1.03-1.21
\$ 75,000+	1.00	---	1.00	---	1.00	---
Marital Status						
Married	1.00	---	1.00	---	1.00	---
Divorced	1.12	1.10-1.15	1.12	1.09-1.16	1.05	0.97-1.13
Separated	1.16	1.11-1.21	1.21	1.13-1.29	1.03	0.89-1.19
Never Married	1.25	1.22-1.28	1.30	1.24-1.36	0.88	0.79-0.98
Widowed	1.11	1.09-1.13	1.14	1.11-1.18	1.06	0.98-1.15
Education						
< High School grad	1.00	---	1.00	---	1.00	---
High School grad	0.88	0.87-0.89	0.86	0.84-0.88	0.82	0.77-0.88
Some College	0.83	0.82-0.85	0.83	0.80-0.86	0.73	0.67-0.79
College grad	0.72	0.70-0.74	0.69	0.66-0.72	0.59	0.53-0.66
>College grad	0.68	0.66-0.70	0.64	0.60-0.67	0.46	0.41-0.53
Urban/Rural						
Urban	1.00	---	1.00	---	1.00	---
Rural	0.97	0.96-0.99	0.99	0.96-1.01	1.02	0.96-1.09
Region						
Northeast	0.94	0.92-0.96	0.91	0.87-0.94	1.04	0.96-1.13
Midwest	0.97	0.95-0.99	0.94	0.91-0.97	1.14	1.05-1.24
South	1.06	1.04-1.08	1.05	1.01-1.08	1.24	1.14-1.34
West	1.00	---	1.00	---	1.00	---
BMI						
<20	1.38	1.35-1.42	1.47	1.41-1.54	1.38	1.26-1.51
20-25	1.00	---	1.00	---	1.00	---
25-30	0.96	0.94-0.97	0.98	0.96-1.01	0.80	0.75-0.85
30-35	1.11	1.08-1.13	1.18	1.14-1.21	0.80	0.73-0.87
>35	1.52	1.47-1.56	1.80	1.73-1.88	0.69	0.60-0.80
Smoking						
Never	1.00	---	1.00	---	1.00	---
Current	2.16	2.12-2.21	2.39	2.32-2.46	15.11	13.70-16.66
Former	1.32	1.30-1.35	1.38	1.35-1.42	4.90	4.44-5.42

Note: All models were adjusted for age, sex, race, income, education, marital status, urban versus rural, census regions, survey year, smoking status, BMI and the complex NHIS survey design.

^aCause-of-death groupings are based on International Statistical Classification of Diseases, Injuries, and Causes of Death, Tenth Revision (ICD-10). Cardiopulmonary disease includes cardiovascular disease (I00-I09, I11, I13, I20-I51), cerebrovascular disease (I60-I69), chronic lower respiratory disease (J40-J47), and influenza and pneumonia (J09-J18). Lung cancer includes C33-C34.

Table S2. Results of model sensitivity analysis comparing hazard ratios (and 95% CIs) for full and sub-cohorts, for complex versus basic CPH models, for models with progressively added control variables, and for alternative exposure and survey periods.

	Cohort	All Causes of Death		Cardiopulmonary		Lung Cancer	
		Hazard Ratio	95% CI	Hazard Ratio	95% CI	Hazard Ratio	95% CI
Complete Complex CPH Model	Full	1.13	1.11-1.16	1.24	1.20-1.29	1.08	0.99-1.18
Complete Basic CPH Model	Full	1.13	1.11-1.15	1.24	1.20-1.27	1.09	1.01-1.17
Complete Complex CPH Model	Sub	1.12	1.08-1.15	1.23	1.17-1.29	1.12	1.00-1.26
Complete Basic CPH Model	Sub	1.13	1.09-1.16	1.24	1.19-1.30	1.12	1.00-1.25
Excluding smoking and BMI	Sub	1.12	1.09-1.15	1.24	1.18-1.29	1.09	0.97-1.22
Basic CPH Model, control for age, sex, race	Full	1.18	1.16-1.20	1.31	1.27-1.34	1.23	1.16-1.32
Basic CPH Model, control for age, sex, race	Sub	1.18	1.15-1.21	1.33	1.27-1.39	1.22	1.10-1.35
+ smoking status	Sub	1.17	1.13-1.20	1.31	1.26-1.37	1.16	1.05-1.29
+ BMI	Sub	1.16	1.13-1.20	1.31	1.26-1.37	1.17	1.05-1.29
+ income	Full	1.20	1.18-1.22	1.33	1.30-1.37	1.27	1.19-1.35
	Sub	1.17	1.14-1.20	1.32	1.27-1.38	1.18	1.06-1.30
+ education	Full	1.17	1.15-1.19	1.30	1.26-1.33	1.20	1.13-1.28
	Sub	1.15	1.12-1.18	1.29	1.24-1.35	1.14	1.02-1.26
+ marital status	Full	1.15	1.13-1.17	1.27	1.24-1.31	1.19	1.11-1.27
	Sub	1.14	1.11-1.17	1.27	1.22-1.33	1.14	1.03-1.26
+ urban/rural	Full	1.13	1.11-1.15	1.26	1.22-1.29	1.14	1.07-1.22
	Sub	1.12	1.09-1.16	1.26	1.20-1.32	1.17	1.05-1.30
+ region	Full	1.14	1.12-1.16	1.27	1.20-1.31	1.10	1.03-1.18
	Sub	1.14	1.10-1.17	1.28	1.22-1.34	1.11	1.00-1.24
+ indicators for each survey year (Complete Basic CPH Model)	Full	1.13	1.11-1.15	1.24	1.20-1.27	1.09	1.01-1.17
	Sub	1.13	1.09-1.16	1.24	1.19-1.30	1.12	1.00-1.25
Basic CPH model; Mean PM _{2.5} 1988-2015 (1988-1998 imputed); Survey years 1986-2014	Full	1.10	1.08-1.11	1.17	1.14-1.19	1.09	1.03-1.15
	Sub	1.09	1.07-1.12	1.17	1.13-1.21	1.09	1.00-1.20
Basic CPH model; Mean PM _{2.5} 1999-2015; Survey years 1999-2014	Full	1.22	1.18-1.27	1.31	1.23-1.39	1.13	0.98-1.30
	Sub	1.17	1.11-1.23	1.23	1.13-1.33	1.16	0.95-1.41

Note: Cause-of-death groupings are based on International Statistical Classification of Diseases, Injuries, and Causes of Death, Tenth Revision (ICD-10). Cardiopulmonary disease includes cardiovascular disease (I00-I09, I11, I13, I20-I51), cerebrovascular disease (I60-I69), chronic lower respiratory disease (J40-J47), and influenza and pneumonia (J09-J18). Lung cancer includes C33-C34.

Table S3. Results of stratified analysis for the sub-cohort comparing hazard ratios (and 95% CIs) associated with 10 µg/m³ PM_{2.5} estimated from the basic CPH model across selected strata of sex, race, age, smoking status, BMI, income, education, marital status, rural/urban, census regions, and survey years. All stratified estimates are adjusted for remaining covariates.

	All Causes of Death		Cardiopulmonary		Lung Cancer	
	Hazard Ratio	95% CI	Hazard Ratio	95% CI	Hazard Ratio	95% CI
SEX						
Male	1.13	1.08-1.17	1.21	1.14-1.29	1.11	0.95-1.29
Female	1.13	1.08-1.17	1.27	1.20-1.35	1.13	0.96-1.33
RACE-ETHNICITY						
Non-Hispanic White	1.11	1.07-1.15	1.25	1.19-1.32	1.12	0.99-1.28
Hispanic	1.20	1.11-1.30	1.19	1.03-1.37	1.28	0.83-1.96
Non-Hispanic Black	1.15	1.05-1.27	1.26	1.08-1.46	0.93	0.64-1.34
Other/unknown	1.10	0.94-1.28	1.29	1.00-1.67	0.91	0.48-1.71
AGE (at survey year)						
Age 18-64	1.19	1.15-1.24	1.30	1.21-1.40	1.15	0.99-1.33
Age 65-74	1.08	1.02-1.14	1.23	1.14-1.33	1.06	0.86-1.30
Age 75-84	1.05	0.99-1.11	1.18	1.09-1.28	1.04	0.77-1.41
SMOKING STATUS						
Never Smoker	1.20	1.15-1.25	1.42	1.32-1.53	1.77	1.26-2.49
Current Smoker	1.09	1.03-1.15	1.16	1.06-1.27	1.01	0.87-1.17
Former Smoker	1.07	1.02-1.12	1.14	1.06-1.23	1.11	0.91-1.35
BMI						
< 20	1.25	1.12-1.39	1.28	1.09-1.52	1.30	0.89-1.89
20-25	1.10	1.05-1.16	1.23	1.14-1.33	1.09	0.91-1.29
25-30	1.14	1.09-1.20	1.26	1.17-1.36	1.24	1.02-1.50
30-35	1.10	1.01-1.18	1.21	1.07-1.37	0.99	0.70-1.39
> 35	1.16	1.04-1.30	1.31	1.10-1.56	0.84	0.46-1.56
INCOME						
\$0-35,000	1.13	1.08-1.17	1.21	1.14-1.28	1.03	0.88-1.22
\$35-50,000	1.15	1.07-1.23	1.33	1.19-1.49	1.50	1.14-1.97
\$50-75,000	1.19	1.11-1.29	1.39	1.22-1.57	1.16	0.87-1.53
\$75,000+	1.07	1.00-1.16	1.19	1.05-1.35	1.00	0.76-1.31
EDUCATION						
< High school graduate	1.15	1.10-1.21	1.19	1.11-1.29	1.10	0.90-1.33
High school graduate	1.11	1.05-1.16	1.23	1.14-1.33	1.11	0.92-1.34
Some college	1.12	1.04-1.19	1.23	1.11-1.37	1.14	0.88-1.46
College graduate	1.12	1.01-1.25	1.45	1.21-1.73	1.12	0.72-1.75

> College graduate	1.13	1.00-1.28	1.32	1.07-1.63	1.35	0.78-2.33
MARITAL STATUS						
Married	1.14	1.10-1.19	1.23	1.15-1.31	1.14	0.97-1.33
Divorced	1.19	1.10-1.28	1.43	1.26-1.62	1.19	0.92-1.55
Separated	1.14	0.96-1.36	0.98	0.74-1.29	1.68	0.87-3.24
Never married	1.23	1.12-1.34	1.39	1.18-1.63	1.18	0.74-1.86
Widowed	1.06	1.00-1.12	1.21	1.11-1.31	0.84	0.65-1.08
URBAN-RURAL						
Urban	1.13	1.10-1.17	1.27	1.20-1.33	1.12	0.98-1.27
Rural	1.10	1.03-1.18	1.15	1.03-1.28	1.09	0.84-1.40
CENSUS REGION						
Northeast	1.10	1.01-1.19	1.18	1.03-1.34	0.91	0.67-1.23
Midwest	1.27	1.18-1.36	1.46	1.30-1.64	1.27	0.97-1.66
South	1.11	1.04-1.19	1.13	1.03-1.25	1.10	0.87-1.39
West	1.09	1.05-1.14	1.24	1.15-1.32	1.10	0.92-1.32
SURVEY YEAR						
1986-1995	1.08	1.04-1.13	1.24	1.17-1.31	1.05	0.90-1.22
1996-2005	1.19	1.14-1.26	1.26	1.16-1.37	1.24	1.02-1.51
2006-2014	1.16	1.06-1.27	1.17	1.01-1.37	1.15	0.81-1.62

Note: Cause-of-death groupings are based on International Statistical Classification of Diseases, Injuries, and Causes of Death, Tenth Revision (ICD-10). Cardiopulmonary disease includes cardiovascular disease (I00-I09, I11, I13, I20-I51), cerebrovascular disease (I60-I69), chronic lower respiratory disease (J40-J47), and influenza and pneumonia (J09-J18). Lung cancer includes C33-C34.

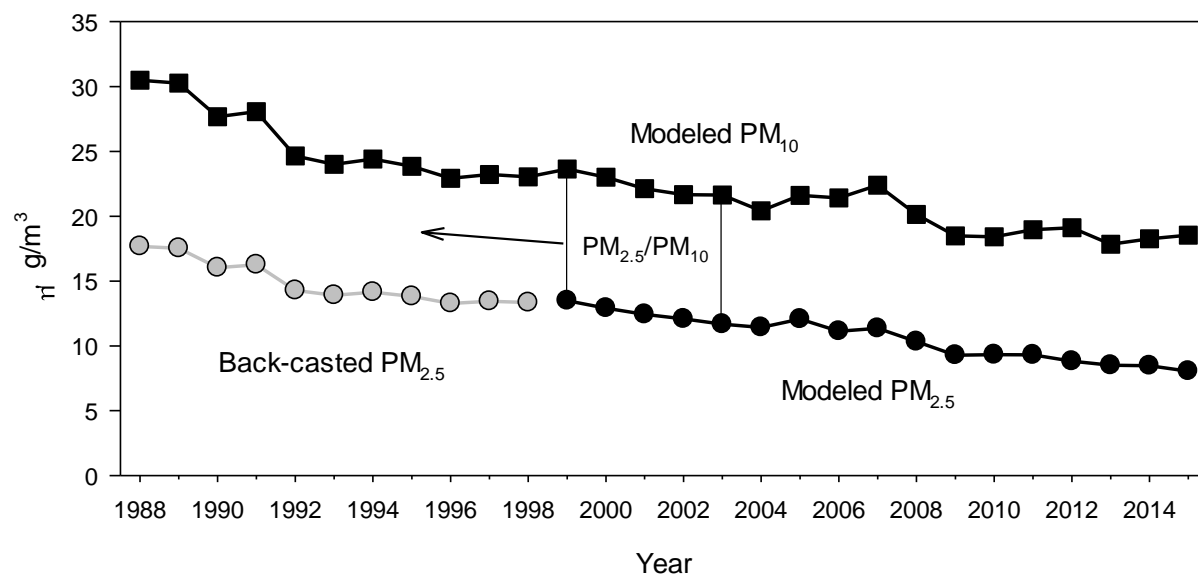


Figure S1. Illustration of approach to estimate back-casted, imputed PM_{2.5} from 1988-

1998. Black circles indicate modeled annual mean PM_{2.5} concentrations for the 17 years (1999–2015) with regulatory monitoring data for PM_{2.5} estimated using the universal kriging modeling framework. Black squares indicate modeled annual mean PM₁₀ concentrations for the 28 years (1988–2015) with regulatory monitoring data for PM₁₀ also estimated using the universal kriging modeling framework. Grey circles indicate the back-casted, imputed PM_{2.5} estimated from 1988-1998 based on modeled PM₁₀ and census –tract mean PM_{2.5}/PM₁₀ ratios for 1999-2003. This back-casting approach was used for each census tract separately. For simple illustration, this figure presents averages across all census tracts (urban and rural) in the contiguous U.S. (average PM_{2.5}/PM₁₀ ratio for 1999-2003 was 0.58).