# *Fine Particulate Air Pollution and Life Expectancy in the United States*

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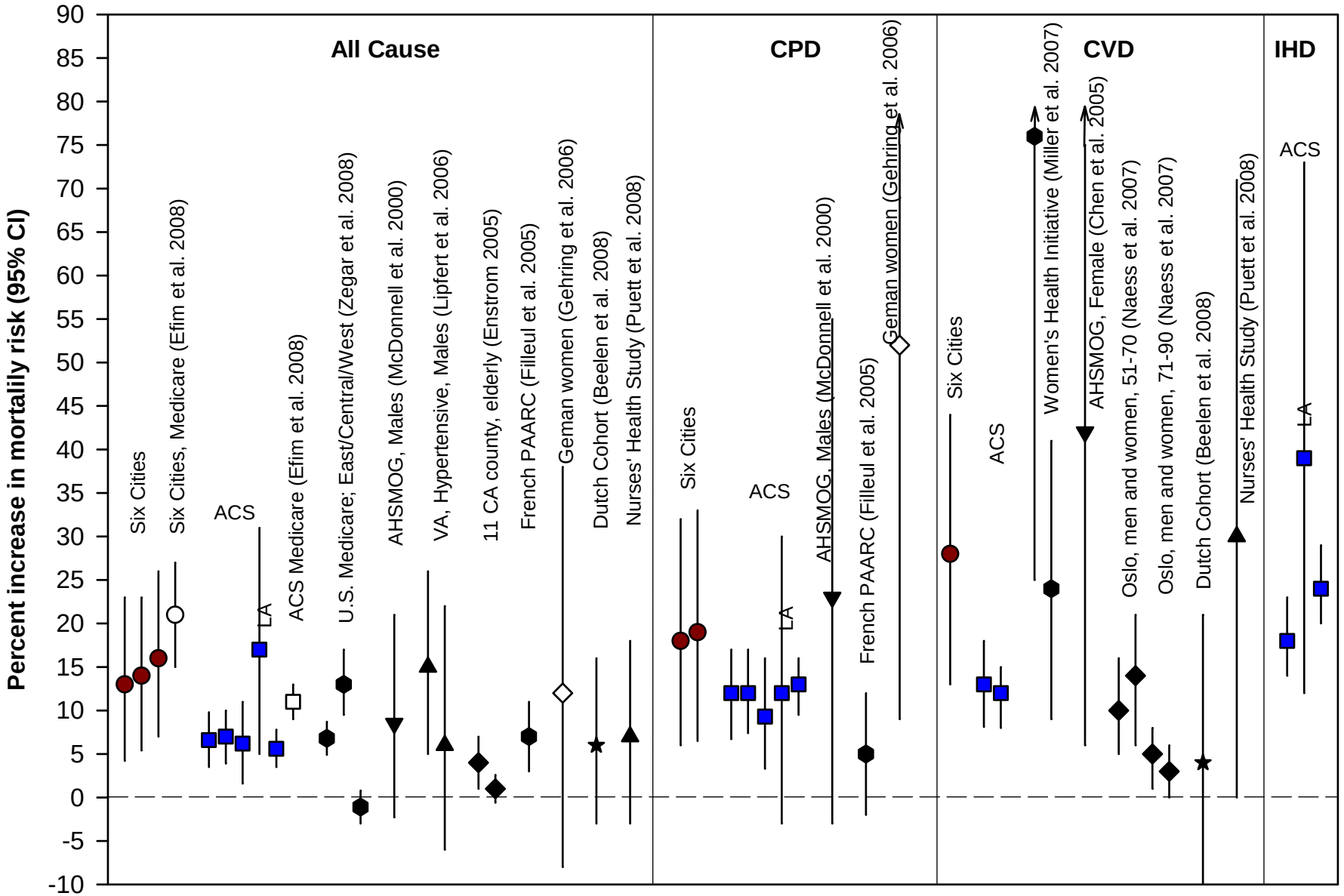
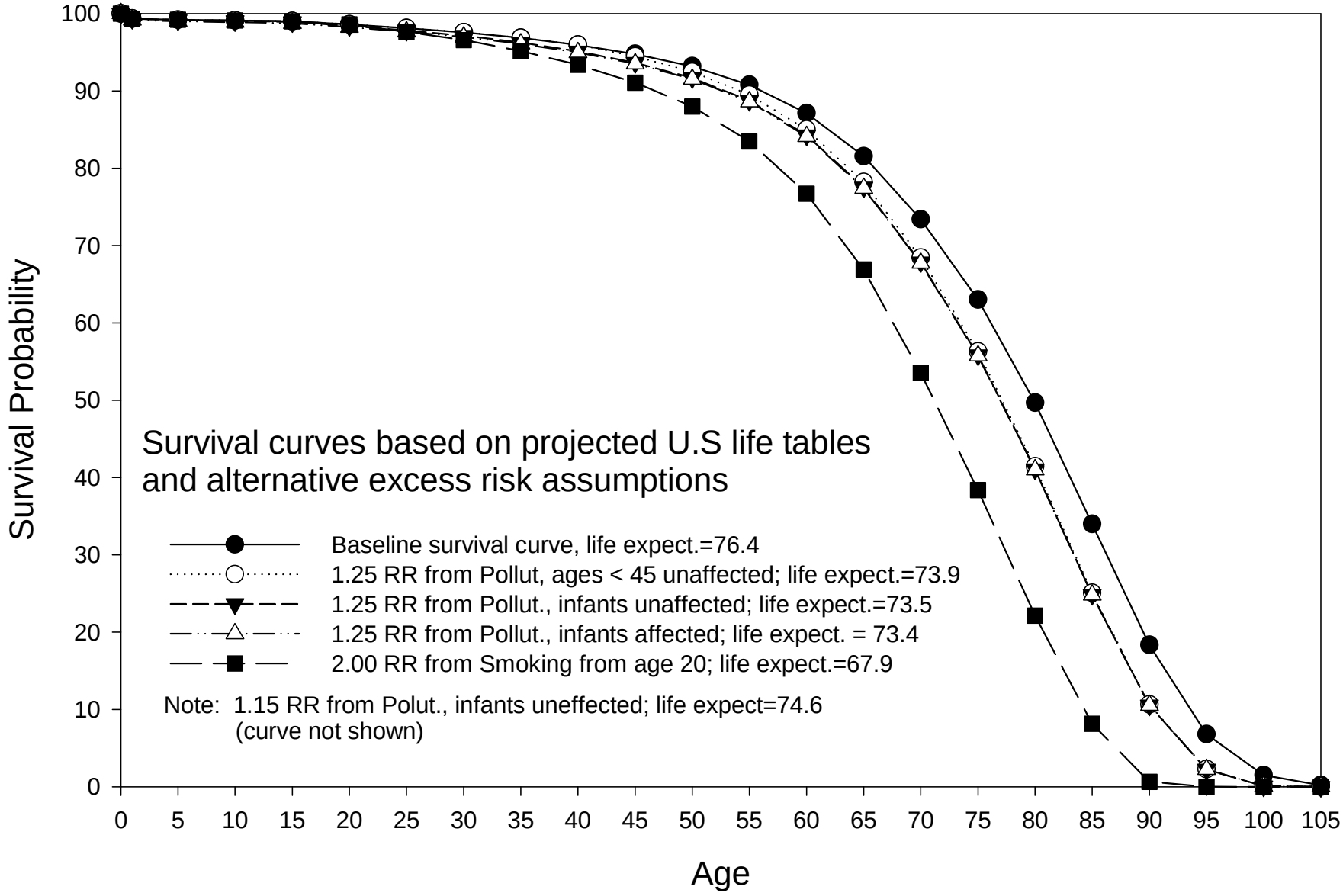
# Summary of estimates in increased mortality risk from cohort studies of long-term exposure



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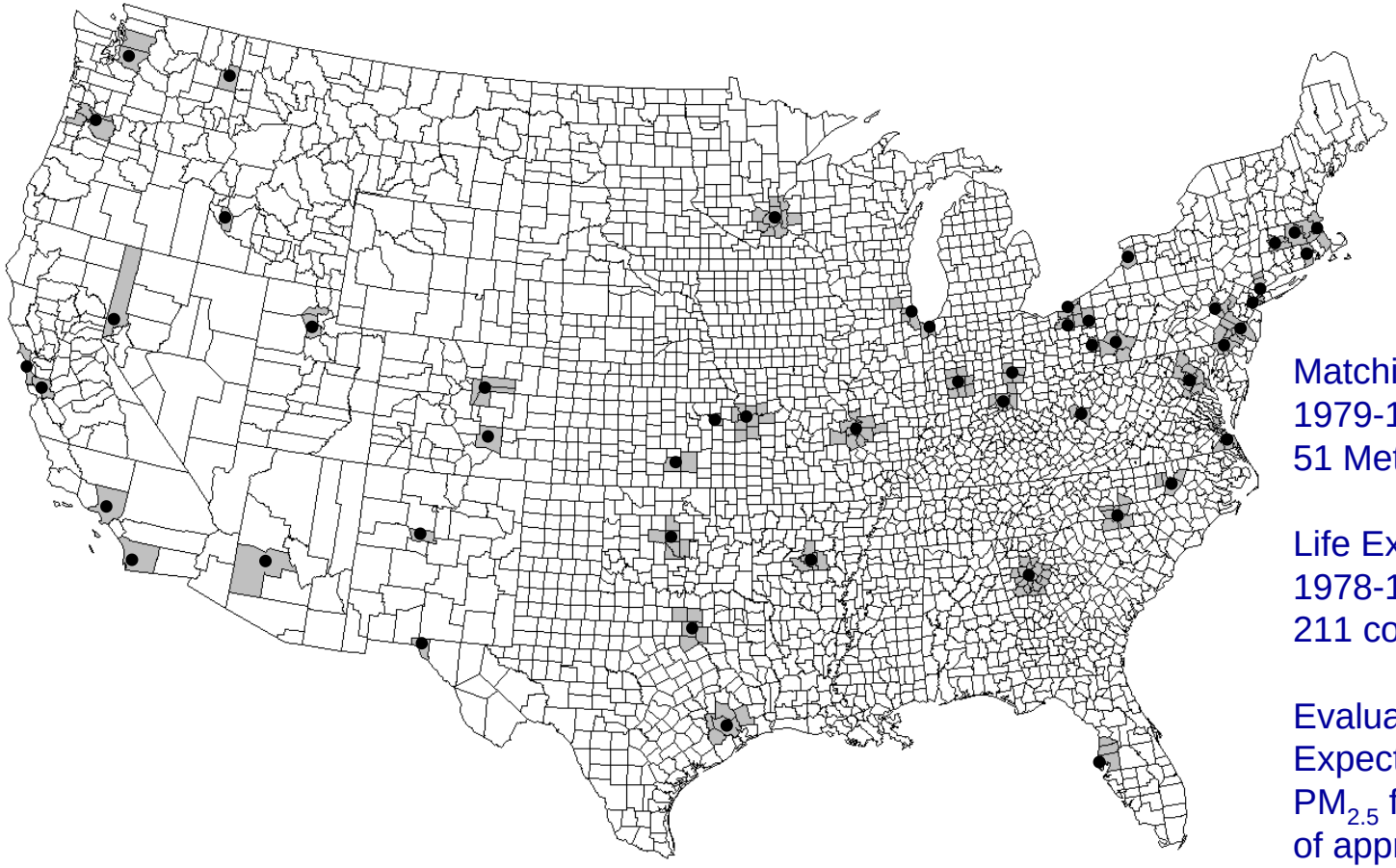
# Fine-Particulate Air Pollution and Life Expectancy in the United States

*C. Arden Pope, III, Ph.D., Majid Ezzati, Ph.D., and Douglas W. Dockery, Sc.D.*

January 22, 2009

Majid Ezzati

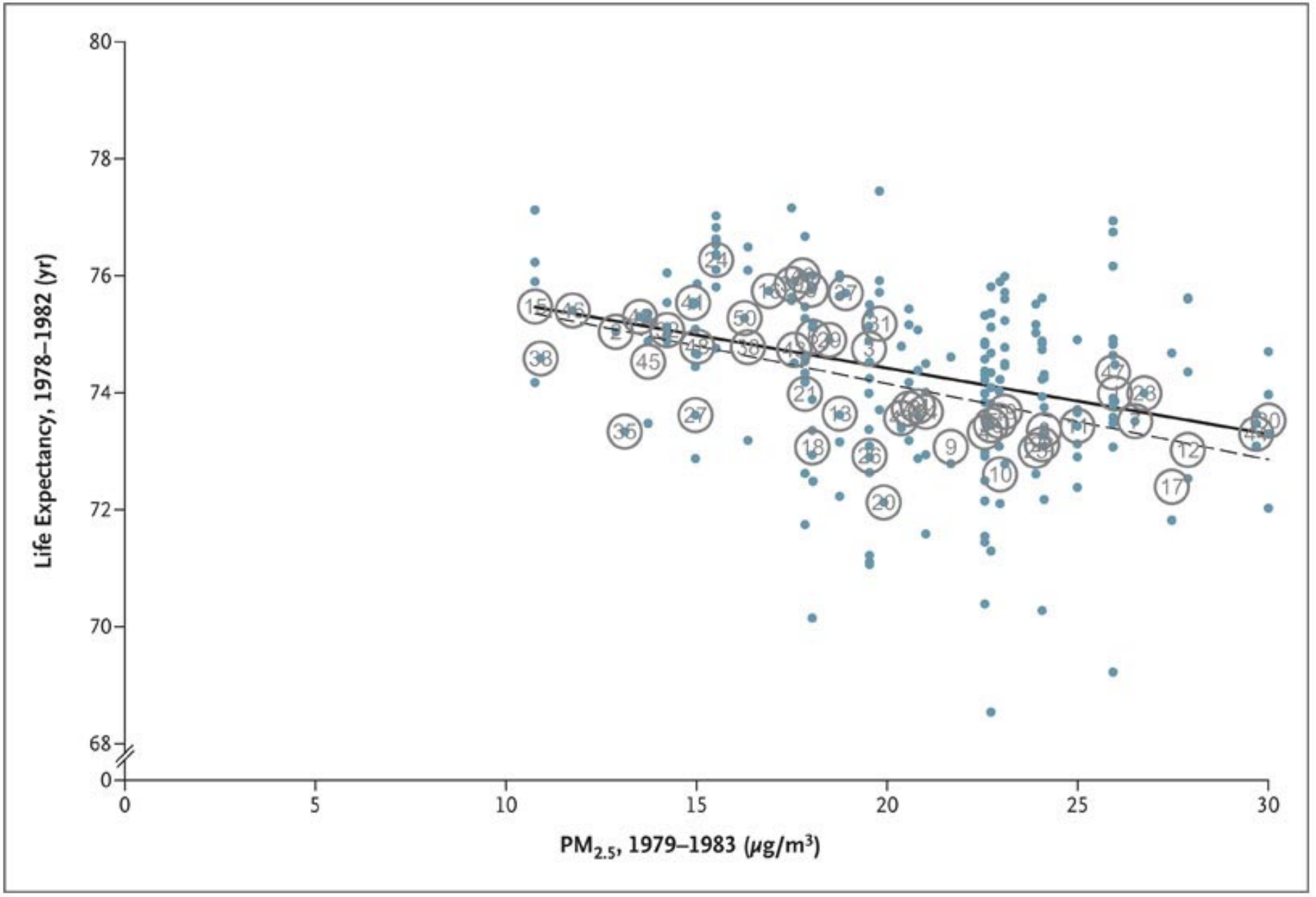
Doug Dockery

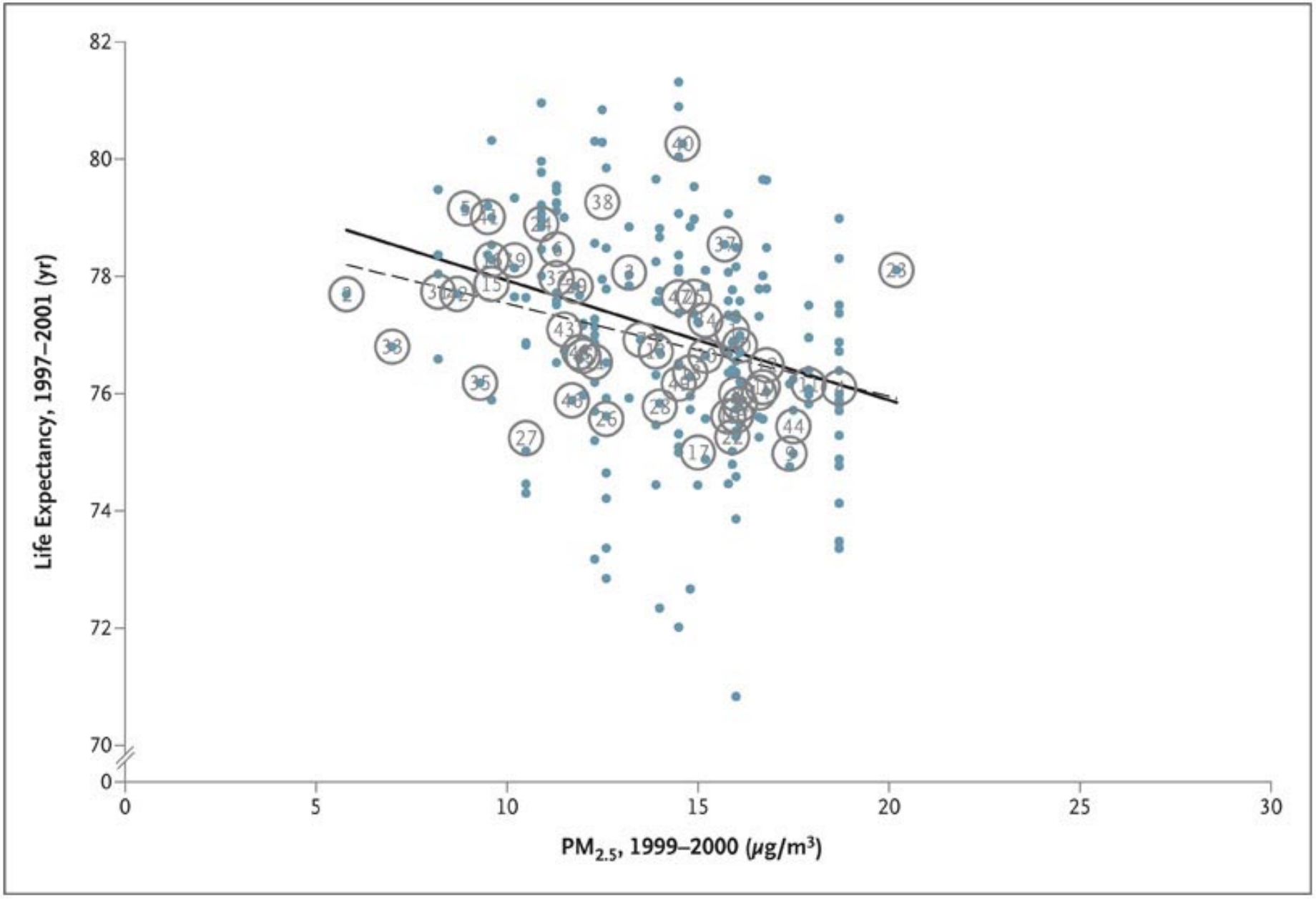


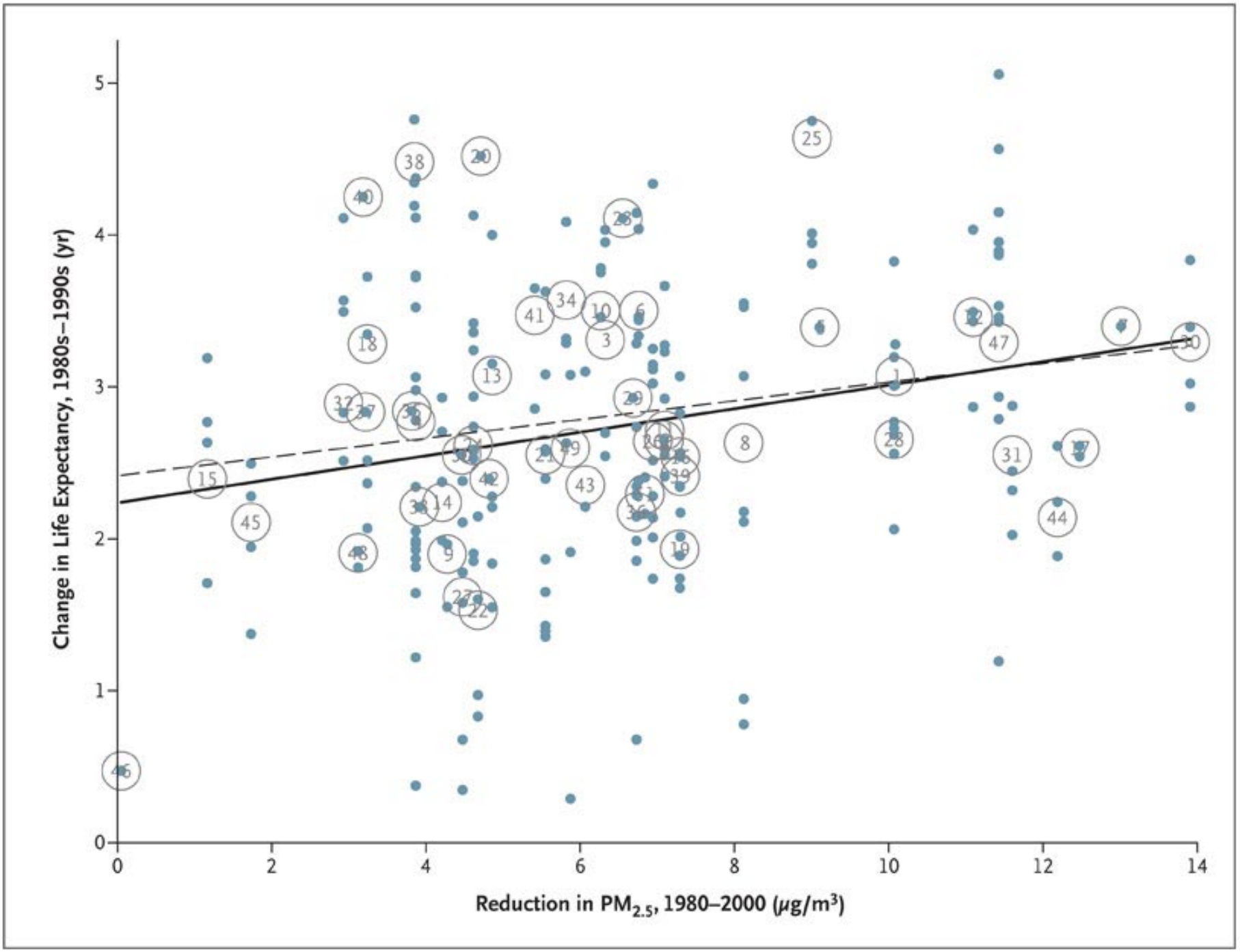
Matching $PM_{2.5}$ data for 1979-1983 and 1999-2000 in 51 Metro Areas

Life Expectancy data for 1978-1982 and 1997-2001 in 211 counties in 51 Metro areas

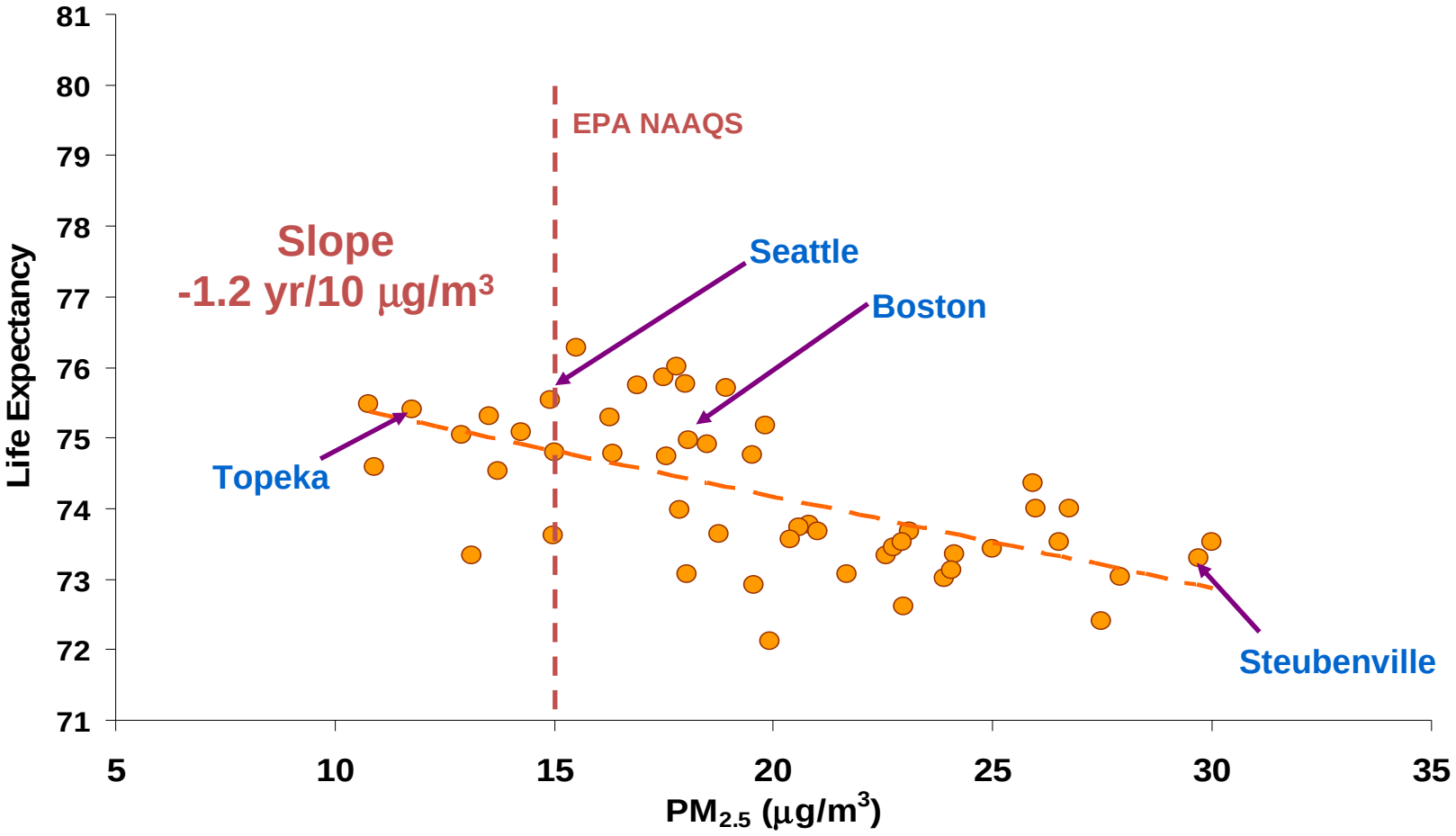
Evaluate changes in Life Expectancy with changes in $PM_{2.5}$ for the 2-decade period of approximately 1980-2000.


80
78
76
74
72
70
68
0
0
5
10
15
20
25
30
Life Expectancy, 1978–1982 (yr)
PM2.5, 1979–1983 (μg/m3)

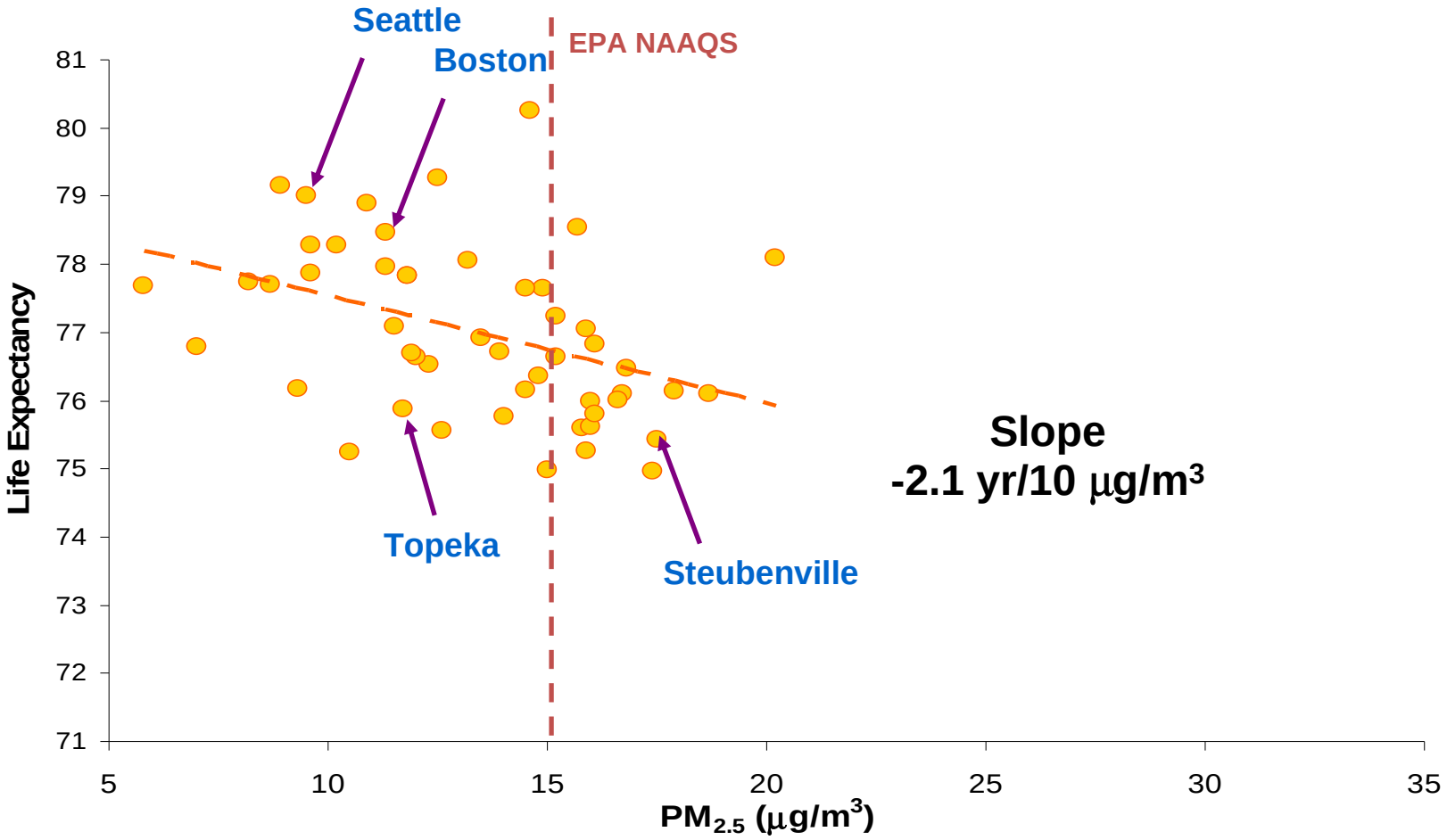

82
80
78
76
74
72
70
0
0
5
10
15
20
25
30
Life Expectancy, 1997–2001 (yr)
PM2.5, 1999–2000 (μg/m3)

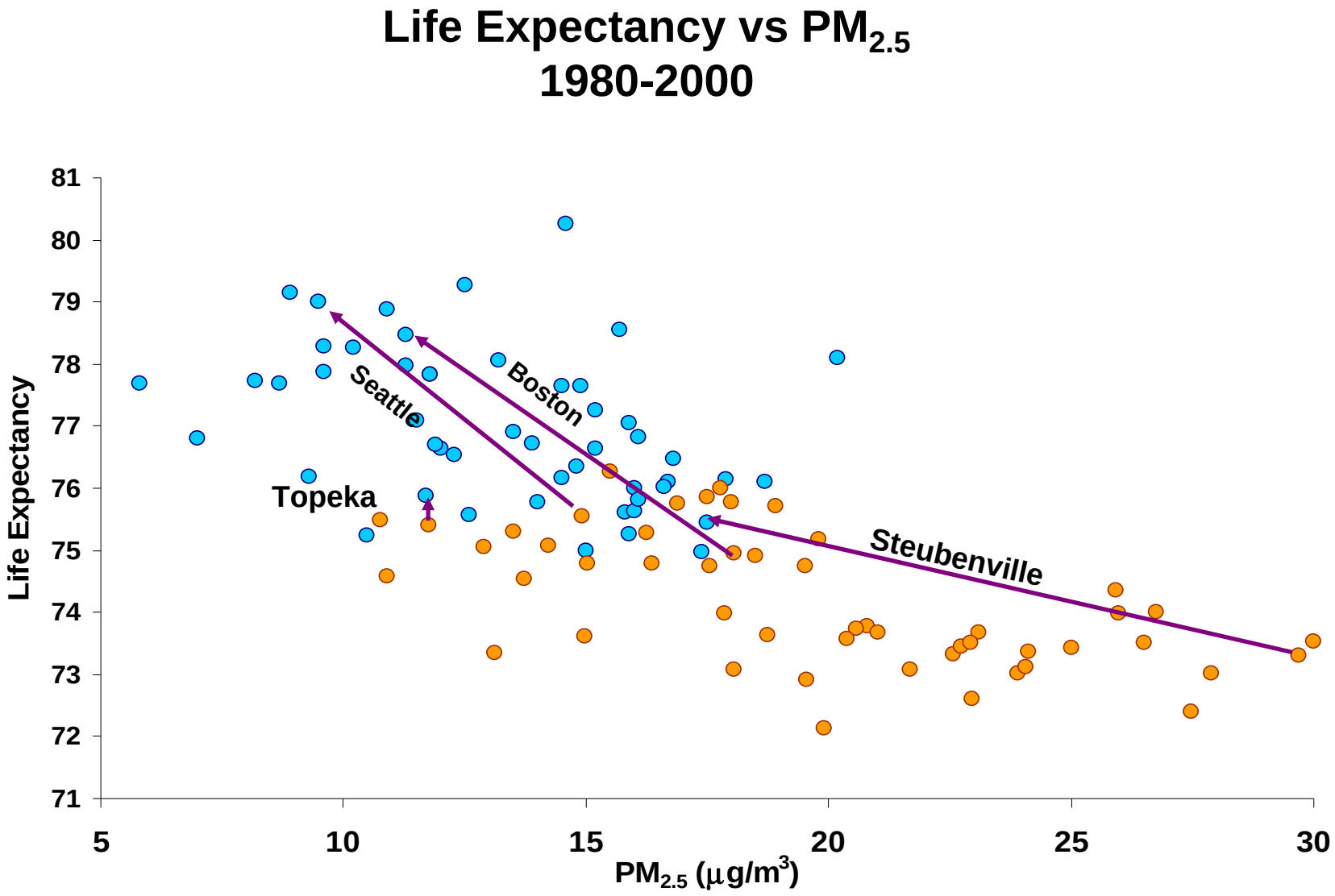

Change in Life Expectancy, 1980s–1990s (yr)
Reduction in $PM_{2.5}$, 1980–2000 ($\mu g/m^3$)
0
1
2
3
4
5
0
2
4
6
8
10
12
14

# Life Expectancy vs $PM_{2.5}$ 1978-82

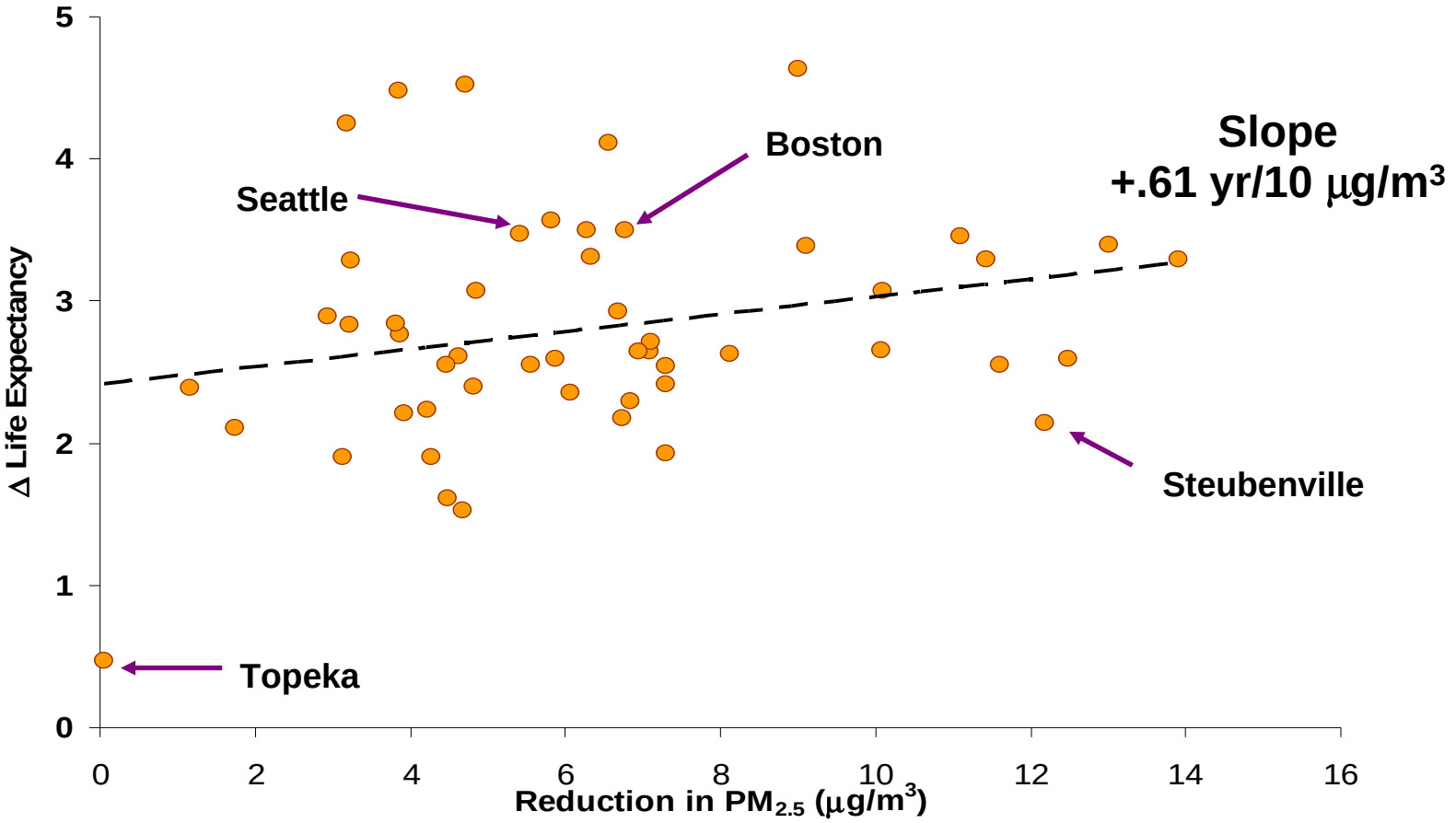


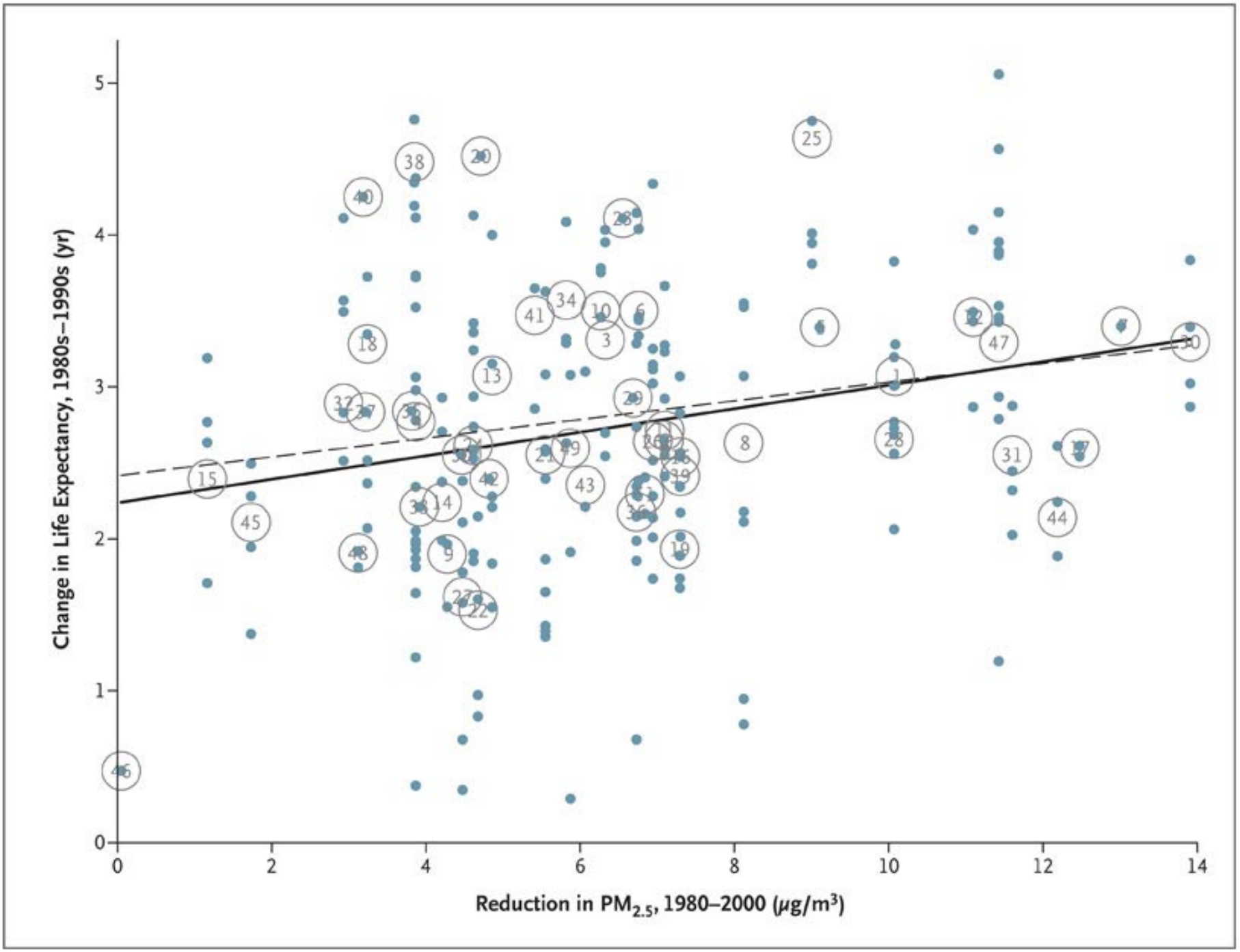
# Life Expectancy vs $PM_{2.5}$ 1997-2001




Life Expectancy vs PM2.5
1980-2000
Life Expectancy
81
80
79
78
77
76
75
74
73
72
71
5
10
15
20
25
30
PM2.5 (µg/m3)
Seattle
Boston
Topeka
Steubenville

# Δ Life Expectancy vs Δ $PM_{2.5}$ 1980-2000



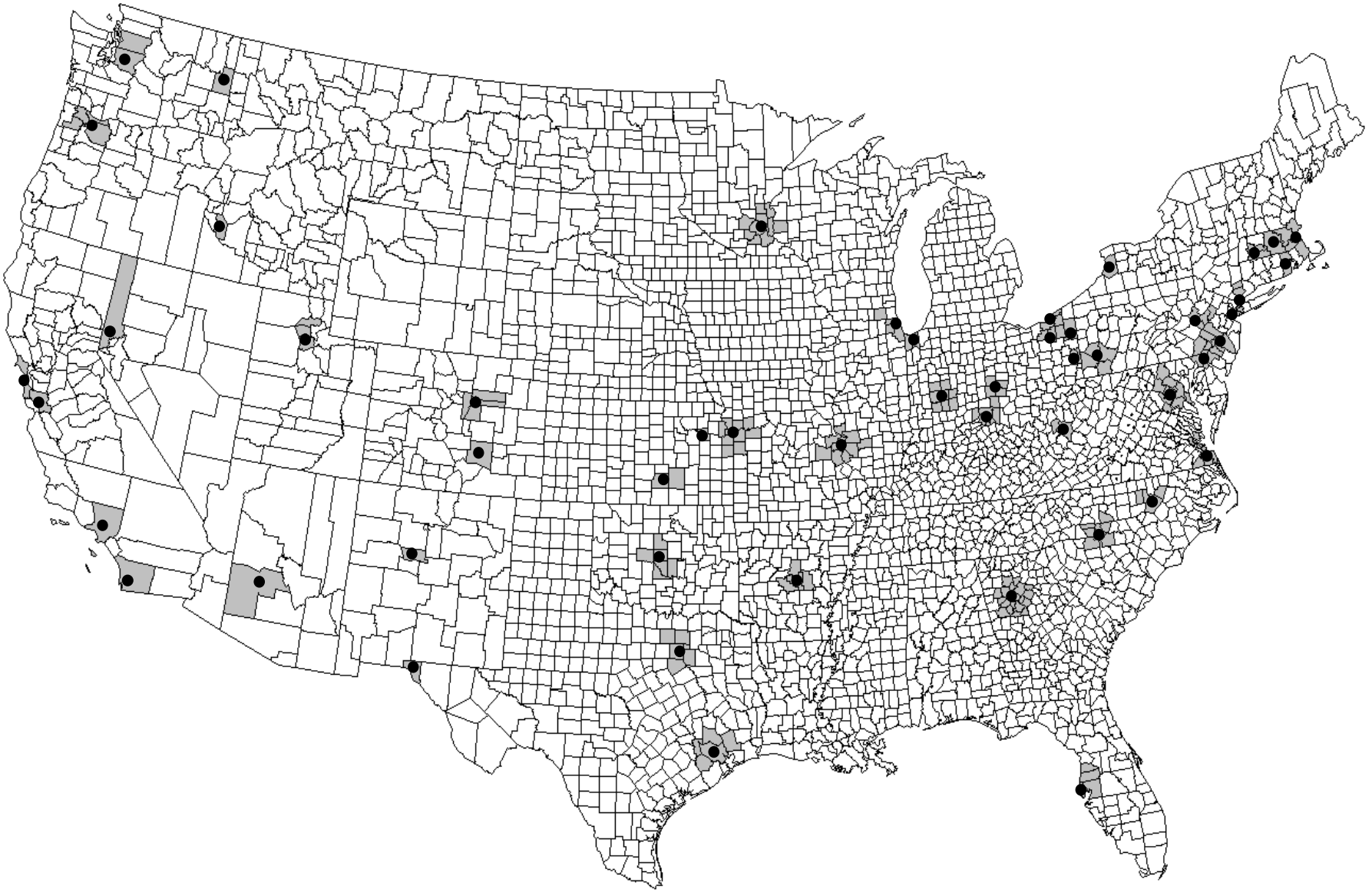

Change in Life Expectancy, 1980s–1990s (yr)
Reduction in $PM_{2.5}$, 1980–2000 ($\mu g/m^3$)
0
1
2
3
4
5
0
2
4
6
8
10
12
14

## Regression analysis

- Regression models were used to control for various socio-economic, demographic, and smoking variables.
- Cross-sectional regression models estimated for both time periods.
- First-difference regression models were estimated.
- Sensitivity analysis included:

1. With and without different combinations of socio-economic, demographic, and smoking variables.
2. Restricting to only counties with >100,000 population.
3. Restricting to only 51 largest counties in each metro area.
4. Estimating population-weighted regression models.
5. Stratifying according to beginning pollution levels.

- Clustered standard errors (clustered by the 51 metro areas) were estimated for all models except for analysis that included only the 51 largest counties in each metro area.



## Covariates included in the regression models

Changes in socio-economic and demographic variables (from U.S. Census Data):

- Per capita income
- Population
- 5-yr in-migration
- High-school graduates
- Urban population
- Black proportion of population
- Hispanic proportion of population

Proxy cigarette smoking variables—available for all 211 counties

- COPD mortality rates
- Lung Cancer mortality rates

Survey-based metro-area estimates of smoking prevalence

- National Health Interview Survey (1978-1980)
- Behavioral Risk Factor Surveillance System (1998-2000)
- Matching data available for only 24 of 51 metro areas

**Table 2.** Results of Selected Regression Models, Including Estimates of the Increase in Life Expectancy Associated with a Reduction in $PM_{2.5}$ of 10 μg per Cubic Meter, Adjusted for Socioeconomic, Demographic, and Proxy Indicators for Prevalence of Smoking.*

| Variable | Model 1 | Model 2 | Model 3 | Model 4 | Model 5† | Model 6‡ | Model 7‡ |
|---|---|---|---|---|---|---|---|
| | | | | *years* | | | |
| Intercept | 2.25±0.21§ | 0.80±0.19§ | 1.78±0.27§ | 1.75±0.27§ | 2.02±0.34§ | 1.71±0.51§ | 2.09±0.36§ |
| Reduction in $PM_{2.5}$ (10 μg/m³) | 0.72±0.29¶ | 0.83±0.20§ | 0.60±0.20§ | 0.61±0.20§ | 0.55±0.24¶ | 1.01±0.25§ | 0.95±0.23§ |
| Change in income (in thousands of $) | — | 0.17±0.02§ | 0.13±0.02§ | 0.13±0.01§ | 0.11±0.02§ | 0.15±0.04§ | 0.11±0.02§ |
| Change in population (in hundreds of thousands) | — | 0.08±0.02§ | 0.05±0.02§ | 0.06±0.02§ | 0.05±0.02§ | 0.04±0.02 | 0.05±0.02¶ |
| Change in 5-yr in-migration (proportion of population)‖** | — | 0.19±0.79 | 1.28±0.80 | — | — | −0.02±1.83 | — |
| Change in high-school graduates (proportion of population)‖ | — | 0.17±0.56 | −0.11±0.53 | — | — | −0.90±0.86 | — |
| Change in urban residence (proportion of population)‖ | — | −0.76±0.32¶ | −0.40±0.25 | — | — | 0.03±1.88 | — |
| Change in black population (proportion of population)‖†† | — | −1.94±0.58§ | −2.74±0.58§ | −2.70±0.64§ | −2.95±0.78§ | −5.06±2.12§ | −5.98±1.99§ |
| Change in Hispanic population (proportion of population)‖†† | — | 1.46±1.23 | 1.33±1.10 | — | — | 2.44±2.22 | — |
| Change in lung-cancer mortality rate (no./10,000 population) | — | — | −0.07±0.02§ | −0.06±0.02§ | −0.07±0.03¶ | 0.01±0.03 | 0.02±0.03 |
| Change in COPD mortality rate (no./10,000 population) | — | — | −0.07±0.02§ | −0.08±0.02§ | −0.09±0.03§ | −0.15±0.06§ | −0.19±0.05§ |
| No. of county units | 211 | 211 | 211 | 211 | 127 | 51 | 51 |
| $R^2$‡‡ | 0.05 | 0.47 | 0.55 | 0.53 | 0.60 | 0.76 | 0.74 |

- 10 μg/m³ decrease in $PM_{2.5}$ associated with ~ 0.61 (± 0.20) years increase in life expectancy
- Not highly sensitive to controlling for socio-economic, demographic, or smoking variables

# Conclusions

- The results of this analysis are generally good news.
- Multiple factors clearly affect life expectancy, but . . .
- These findings provide evidence that improvements in air quality contribute to measurable improvements in life expectancy in the U.S.
- This evidence in consistent with indirect estimates based on pollution-related elevated mortality risks from the cohort and related studies.