



Short communication

Tradeoffs between income, air pollution and life expectancy: Brief report on the US experience, 1980–2000

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ARTICLE INFO

Article history:

Received 4 June 2015

Received in revised form

21 July 2015

Accepted 13 August 2015

Keywords:

Air pollution

Life expectancy

Income

Particulate pollution

Economic tradeoffs

ABSTRACT

During the period of 1980–2000, the US obtained substantial reductions in air pollution and improvements in life expectancy (LE). Multiple factors contributed to improved health. This report explores and illustrates trade-offs between income, air pollution, and LE. Both improved air quality and income growth contributed to LE gains – without evidence of substantial negative tradeoffs between air pollution and income. Cleaner air may be considered an “economic good” with contributions to health, wellbeing, and human capital.

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1. Introduction

Although the relationship between income and health is complicated and not fully understood, there is evidence that income can influence public health by allowing for better access to health care, improving standards of living, and providing other amenities that contribute to wellbeing (Deaton, 2003; Mackenbach et al., 2008). Improved health may also contribute to economic growth (Bloom and Canning, 2000). There is a large body of evidence that exposure to air pollution, especially fine particulate matter air pollution (PM_{2.5}) can have adverse effects on cardiovascular and pulmonary health (Brook et al., 2010; Gauderman et al., 2015) and these adverse health effects are observed in increased mortality risks (Pope et al., 2002; Lepeule et al., 2012; Hoek et al., 2013; Beelen et al., 2014) and are reflected in changes in life expectancy (Correia et al., 2013). Because there are economic costs (and benefits) associated with air pollution abatement, there may be important trade-offs between efforts to reduce air pollution and efforts to increase economic well-being as reflected in per capita income.

During the two-decade period of 1980–2000 there was substantial improvement in air quality evidenced by reductions in PM_{2.5} concentrations in many metropolitan areas in the US and there was evidence that areas with larger reductions in air

pollution experienced greater increases in life expectancy (LE), even after controlling for various demographic and socioeconomic factors and controlling for changes in cigarette smoking (Pope et al., 2009). The objective of this note is to briefly explore and illustrate the potential trade-offs between income, air pollution, and LE that occurred in the US between approximately 1980 and 2000.

2. Methods

This analysis is based on 211 county-based units that included 51 metropolitan areas of the US with available PM_{2.5} estimates for approximately the beginning and end of the two-decade period of 1980–2000, a period of some of the largest improvements in air quality in the US. Differential changes in LE, income, and PM_{2.5} across this period were explored. First-difference regression models were used to evaluate the change in LE associated with changes in PM_{2.5} and income adjusting for changes in various other socioeconomic, demographic, and proxy smoking variables. Details regarding how the data were collected and compiled were as previously reported (Ezzati et al., 2008; Pope et al., 2009) with one exception. Because of discrepancies in the 1980 high school graduation data, this current analysis uses changes in high school graduates based on graduation rates recompiled from 1980 and 2000 census files (United States Census Bureau, 1980, 2000).

Statistical analysis included computing descriptive statistics of all variables in the analysis, including means, standard deviations,

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and Pearson Correlation coefficients (and *p*-values) between LE, income, and PM_{2.5} and all of the other variables. Similar to analysis conducted previously, (Pope et al., 2009) first-difference regression models were estimated by regressing increases in LE against reductions in PM_{2.5}, changes in incomes, and changes in other covariates. Clustered standard errors (clustered by the 51 metropolitan areas) were estimated. Models were estimated using PROC SURVEYREG in SAS, version 9.4 (SAS Institute). In addition, a flexible three dimensional surface of the associations between change in LE, reduction in PM_{2.5}, and increase in income was estimated. Specifically a bivariate thin-plate smoothing spline of changes in LE with respect to increase in income and reduction in PM_{2.5} controlling for changes in population, proportion of black population, and lung cancer and COPD mortality rates was estimated using PROC GAM, METHOD=GCV (generalized cross validation) in SAS, version 9.4 (SAS Institute).

3. Results

Table 1 provides the means (and SD) of the variables and also provides unadjusted correlation coefficients between changes in LE, PM_{2.5}, and income. Changes in LE were significantly associated with reductions in PM_{2.5}, but they were even more strongly associated with changes in income and changes in lung-cancer or COPD mortality, which were used as proxy indicators for changes in smoking. Importantly, changes in income were not correlated with changes in PM_{2.5}.

Table 2 provides the estimated regression coefficients (SE) for increase in LE associated with changes in PM_{2.5}, real income and other variables for the full and a parsimonious regression model (model that includes only selected statistically significant (*p* < 0.05) variables). These results indicate that a 10 µg/m³ decrease in long-term average PM_{2.5} was associated with an approximately 0.61 ± 0.20 increase in years of LE. They also indicate that a \$10,000 increase in per capita income was associated with an approximately 1.26 ± 0.14 increase in years of LE. These results are not sensitive to model selection and they are nearly identical to those previously reported (Pope et al., 2009). They suggest an approximately comparable increase in LE from either a 10 µg/m³ reduction in PM_{2.5} or a \$5000 increase in real, per capita income.

Fig. 1, Panel A, presents a bivariate thin-plate smoothing spline of changes in LE with respect to changes in income and PM_{2.5} controlling for changes in population, proportion of black population, and proxy measures of smoking. Moving from the lower left corner (darker red) to the upper left corner (darker blue)

Table 2

Estimated regression coefficients (SE) for increase in life expectancy associated with changes in PM_{2.5}, income and other variables for full and parsimonious regression models.

Variables	Full model	Parsimonious model ^a
ΔPM _{2.5} – reduction in PM _{2.5} (µg/m ³)x10	0.61 (0.20)	0.61 (0.20)
ΔIncome – change in income (1000s of \$)	1.33 (0.15)	1.26 (0.14)
x10		
ΔPop – change in population ^b	0.05 (0.02)	0.06 (0.02)
ΔMig – change in 5-yr in-migration ^c	0.64 (0.85)	
ΔHS – change in high-school graduates ^c	1.26 (0.80)	
ΔUrban – change in urban residence ^c	–0.58 (0.26)	
ΔBlack – change in black population ^c	–2.62 (0.58)	–2.70 (0.64)
ΔHisp – change in Hispanic population ^c	1.70 (1.21)	
ΔLC – change in lung-cancer mortality ^d	–0.07 (0.02)	–0.06 (0.02)
ΔCOPD – change in COPD mortality ^d	–0.08 (0.02)	–0.08 (0.02)
Number of county units	211	211
R ²	0.55	0.53

^a Parsimonious model includes only selected statistically significant (*p* < 0.05) variables.

^b In hundreds of thousands.

^c Proportion of population.

^d Number/10,000 population.

illustrates a potential increase in LE of approximately 2.5 years resulting from large increases in income and reductions in PM_{2.5}. Moving along the iso-LE lines (contour lines) illustrates relationships between changes in PM_{2.5} and income that hold LE constant. For example, following along any iso-LE line from left to right illustrates reductions of PM_{2.5} accompanied with reductions in per capita income than maintains constant LE. This flexible fitting of the changes in LE, income, and PM_{2.5} illustrates reasonably coherent associations that are approximately consistent with the effect estimates from the more simple linear regression results presented in Table 2. Overall the results indicate that improved LE can be obtained by increased real per capita income and reduced air pollution. Furthermore, the iso-LE lines demonstrate little overall convexity, suggesting a high degree of substitutability between reductions in air pollution and changes in income, in terms of effect on changes in LE.

Fig. 1, Panel B, presents increases in income plotted against reductions in PM_{2.5} and illustrates almost no correlation between these two variables. As reported in Table 1, there was only a slight, statistically insignificant negative association between changes in income and PM_{2.5}. The four metro areas with the largest reductions in air pollution (Pittsburg, PA; Buffalo, NY; Gary, IN; and Steubenville, OH), were industrial cities that experienced declining

Table 1

Mean (and SD) of analysis variables and Pearson Correlation coefficients (and *p*-values).

Variables	Mean (SD)	Pearson Correlation coefficients (p-Values)		
		ΔLE	ΔPM _{2.5}	ΔIncome
ΔLE – change in Life Expectancy (yrs)	2.72 (0.93)	1.00	0.23 (0.01)	0.56 (0.01)
ΔPM _{2.5} – reduction in PM _{2.5} (µg/m ³)	6.52 (2.94)	0.23 (0.01)	1.00	–0.03 (0.71)
ΔIncome – change in income (1000s of \$)	8.49 (3.16)	0.56 (0.01)	–0.03 (0.71)	1.00
ΔPop – change in population ^a	0.99 (2.26)	0.23 (0.01)	–0.13 (0.06)	0.03 (0.66)
ΔMig – change in 5-yr in-migration ^b	–0.01 (0.06)	0.01 (0.94)	0.01 (0.92)	0.04 (0.54)
ΔHS – change in high-school graduates ^b	0.16 (0.07)	–0.21 (0.01)	–0.07 (0.34)	–0.11 (0.10)
ΔUrban – change in urban residence ^b	0.20 (0.18)	–0.09 (0.21)	–0.07 (0.30)	0.18 (0.01)
ΔBlack – change in black population ^b	0.02 (0.06)	–0.13 (0.06)	0.03 (0.63)	–0.10 (0.13)
ΔHisp – change in Hispanic population ^b	0.03 (0.04)	0.15 (0.03)	–0.06 (0.38)	–0.01 (0.86)
ΔLC – change in lung-cancer mortality ^c	2.35 (2.77)	–0.47 (0.01)	–0.18 (0.01)	–0.30 (0.01)
ΔCOPD – change in COPD mortality ^c	4.45 (2.43)	–0.46 (0.01)	–0.16 (0.02)	–0.30 (0.01)

^a In hundreds of thousands.

^b Proportion of population.

^c Number/10,000 population.

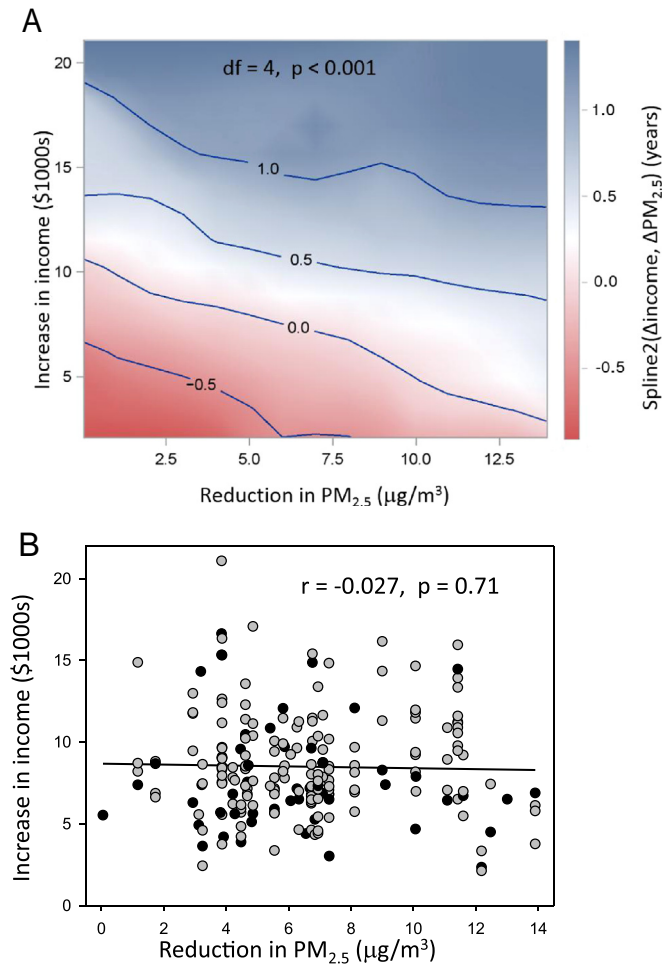


Fig. 1. Panel A – Bivariate thin-plate smoothing spline of changes in life expectancy (illustrated by color contrasts from red to blue and iso-LE or contour lines) with respect to increase in income and reduction in $PM_{2.5}$ controlling for changes in population, proportion of black population, and lung cancer and COPD mortality rates. Panel B – Increase in income plotted against reductions in $PM_{2.5}$ (black dots indicate central urban counties). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

polluting industries and had relatively low income growth. Nevertheless, the results suggest that reductions in air pollution were achieved without apparent substantial loss of economic wellbeing.

4. Discussion and conclusions

The two-decade period of 1980–2000 in the US was a period that experienced substantial reductions in air pollution. Based on observations of metropolitan areas with adequate air pollution data during this period, there are multiple factors that resulted in increased LE. The empirical evidence indicates that both increases in real per capita income and reductions in air pollution contributed to improved public health as reflected in improvements in LE. Regarding the tradeoffs between changes in income, and reduced air pollution, there were generally LE benefits from both, but there was no overall correlation between changes in income and reduction in pollution – suggesting that there were no substantive tradeoffs between improvements in air pollution and real income and overall economic growth.

The major limitation of this analysis is that the interactions between various endogenous and exogenous social, economic, public policy, and environmental factors and relationships were and are far more complicated than can be elucidated in a single case study. These observed LE associations with declining pollution and rising incomes and the nearly uncorrelated changes in incomes and air pollution are not necessarily generalizable to different places and times. Nevertheless, the 1980–2000 period in the US was remarkable. It provided an example of improved air quality during a period of economic growth and improving prosperity that contributed to gains in public health with little evidence of substantial negative tradeoffs between increased incomes and reduced air pollution.

Certainly these results suggest that reductions in air pollution that are extremely costly and result in large loss of income or loss of gains in income would be counterproductive. On the other hand, cleaner air is an “economic good” with positive contributions to health, wellbeing, and human capital. As with the provision of other economic goods, private and public policy efforts and activities that help achieve better air quality may actually promote or contribute to economic prosperity in addition to improving public health.

Funding sources

Mary Lou Fulton Professorship, Brigham Young University.

Declaration of conflict of interest

None.

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