Estimating Mortality and Economic Costs of Particulate Air Pollution in Developing Countries: The Case of Nigeria

Natina Yaduma, Mika Kortelainen and Ada Wossink

American University of Nigeria

17th March. 2017
Society for Benefit-Cost Analysis 2017 Annual Conference

Outline of Presentation

- Introduction
- Methods and Key Concepts
- Results
- Conclusion

Introduction

- Man's economic activities lead to external consquencies:
  - Environment
  - Human Health
- Air pollution (AP) poses serious health hazards ranging from common flus to premature death
- However, policy makers are not only concerned about the linkage of AP and adverse human health
- Consequently, benefit cost assessment of health and economic cost (H&E) is key in decision making

- Types of air pollutants: particulate matter (PM), nitrogen oxide, sulphur oxide, ozone e.t.c
- Epidemiological studies have identified PM as most hazardous to human health
  - Influenza, bronchitis, pneumonia and asthma
  - premature mortality
- Measured in $\kappa g / m^3$ and PM_{10} is the most common measure of inhalable PM
- Two pollution episodes sparked public awareness on the mortality effects of particulate pollution
  - Toxic fogs in Donora (Pennsylvania) between 25th and 31st Oct 1948 that claimed 20 lives
  - Fogs in London between 5th and 8th Dec 1952 that killed about 4000 people

- Studies that monetarise mortality effect show enormous losses from AP:
  - Particulate pollution cost Singapore $3.7b in 1999 (Quah and Boon, 2003)
  - Cost Tianjin (China) $1.1b in 2003 (Zhou and Tol, 2005)

- Objectives:
  1. Compare two benefit transfer used in estimating VSLs for low-income countries
  2. To estimate the mortality cost of particulate pollution in Nigeria.
  3. To monetise the mortality related benefits associated with mitigating PM_{10} pollution in Nigeria.

Methods and Key Concepts

- The Value of Statistical Life (VSL)
  - Willingness to pay for a marginal reduction in risk
  - Ascribing monetary values to mortality costs
- Ways of measuring VSL
  - Consumer behaviour studies
  - Wage-risk studies
  - Contingent valuation studies
- US VSL is $5.9m (Viscusi, 2004) and Chile's VSL is $630,000 (Ortuzar et al, 2000)
- Dire shortage of VSL studies in LDCs
  - Data scarcity
  - Huge costs
- Need for a affordable and credible means of estimating VSL for LDCs

- Benefit Transfer Approach is used in analysing policies in the absence of original data collection
  - Saves time and enormous costs involved in conducting VSL studies
- The Value Transfer Method:

$$VSL_{NIG} = VSL_{US} * \left(\frac{Y_{NIG}}{Y_{US}}\right)^{e} \tag{1}$$

  - Despite the assumption e=1 in most studies, there is no consensus on the choice of e
  - e is not constant but varies depending on the income level of the country of interest
  - Most empirical studies worldwide estimate $0.46 \preceq e \preceq 2.3$
  - The choice of e is of prime imprtance to countries with very low incomes
  - Robinson and Hammitt (2009) suggest the use of 1.0, 1.5 and 2.0 for e
  - Little empircal evidence exists regarding the accuracy of the method
  - Most importantly, the method assumes that income disparity is the only factor accounting for differences in VSL

- Meta-regression Analysis:

$$VSL = f(income,\ fatal\ risk,\ awareness\ on\ fatal\ risks,\ life\ expectancy, RP, CV, WR) + \varepsilon \quad (2)$$

$$VSL_i = \beta' X_i + \varepsilon_i\ , i = 1, 2, ..., 83 \quad (3)$$

- Proxies in capturing the variables in the model:
  - GNI per-capita in 2006 PPP for income
  - Crude mortality rate captures risk
  - Average years of education of each country, school life expectancy, captures individuals' awareness of the fatal dangers
  - Life expectancy at birth captures individuals life expectancy in each country
- The best specification is premised on the model providing a prediction with significant regressors only

- The Mortality Cost of Particulate Pollution
  - Dose Response Functions (DRFs) show expected Δ in mortality per unit Δ in PM_{10} concentration
  - Expressed as $\%\Delta$ mortality due to a given ΔPM_{10} pollution
  - Epidemiology has developed Dose Response Coefficients (DRCs) to be used in health cost studies. See table 1 below:

Table 1: PM_{10} Dose Response Coefficients for Mortality Health Effect

Lower Coefficient	Upper Coefficient
0.096	0.13

- Health outcome is small per unit change in pollution
- A DRC of 0.096 $\implies$ 0.0096. A single κg ΔPM_{10} will have a very little impact on crude mortality rate

- Steps used in estimating the fatal costs of particulate pollution:
    1. Establish the annual average level of ambient PM_{10}
    2. Relate the concentration to mortality using DRFs
    3. Relate the DRFs to the stock at risk
- The general equation of estimating mortality effect is:

$$H_{mortality,PM_{10}} = b_{mortality,PM_{10}} * crudemortalityrate * POP_i * dPM_{10} \quad (4)$$

- WHO annual average PM_{10} air quality guideline of 20 $\kappa g/m^3$ in computing dPM_{10}
- Use VSL to provide a monetary estimate of the mortal costs of AP
- Finally, for economic cost estimate, relate the best VSL estimate to be obtained with the mortality cost estimate

$$TC_{mortality,PM_{10}} = VSL_{NIG} * H_{mortality,PM_{10}} \quad (5)$$

Data

- Value Transfer Method
  - US EPA VSL of $6.655m for analyses of reduced mortality from AP
- Meta-regression

Data

- Value Transfer Method
  - US EPA VSL of $6.655m for analyses of reduced mortality from AP
- Meta-regression
  - VSL estimates for different studies from lit rev in Viscusi (2003) and Aldi (2000)

Data

- Value Transfer Method
  - US EPA VSL of $6.655m for analyses of reduced mortality from AP
- Meta-regression
  - VSL estimates for different studies from lit rev in Viscusi (2003) and Aldi (2000)
  - Recent studies from key word searches from search engines such as ScienceDirect and Econ Lit

Data

- Value Transfer Method
  - US EPA VSL of $6.655m for analyses of reduced mortality from AP
- Meta-regression
  - VSL estimates for different studies from lit rev in Viscusi (2003) and Aldi (2000)
  - Recent studies from key word searches from search engines such as ScienceDirect and Econ Lit
  - VSL studies from 83 studies - 20 countries

Data

- Value Transfer Method
  - US EPA VSL of $6.655m for analyses of reduced mortality from AP
- Meta-regression
  - VSL estimates for different studies from lit rev in Viscusi (2003) and Aldi (2000)
  - Recent studies from key word searches from search engines such as ScienceDirect and Econ Lit
  - VSL studies from 83 studies - 20 countries

  - GNI pc and life expectancy at birth from WDI (2011)

Data

- Value Transfer Method
  - US EPA VSL of $6.655m for analyses of reduced mortality from AP
- Meta-regression
  - VSL estimates for different studies from lit rev in Viscusi (2003) and Aldi (2000)
  - Recent studies from key word searches from search engines such as ScienceDirect and Econ Lit
  - VSL studies from 83 studies - 20 countries

  - GNI pc and life expectancy at birth from WDI (2011)
  - School life expectancy and crude mortality rate from UN Stats Division (2011)

Results

- Value Transfer Method:
  - Use USEPA approved VSL of $6,655,000 for the analysis of reduced mortality from air regulations

$$VOSL_{NIG} = \$6,655,000 * \left(\frac{1{,}790}{44{,}820}\right) = \$6,655,000 * 0.0399^{e}$$

Table 2: Nigeria's Value Transfer Value of Statistical Life Estimations

	Income elasticity for fatal risk reduction		
	1.0	1.5	2.0
$VOSL_{NIG}$	$265,784	$53,115	$10,615

- Meta-regression:

Table 3: Summary of OLS Regression Results for Meta-regression Analysis and Predicted Value of Statistical Life for Nigeria

Dep Variable: lnVSL number of observations = 83

Expl Var	1a	2a	3a
ln(gnipc)	1.101 (0.687)	1.295* (0.154)	1.409* (0.179)
ln(risk)	1.642** (0.670)	1.735* (0.399)	–
ln(educ)	1.622 (1.409)	–	–
ln(age)	-3.060 (5.193)	–	–
CV	0.997* (0.323)	1.920* (0.292)	0.987* (0.296)
WR	1.189* (0.271)	1.167* (0.262)	1.085* (0.259)
Cons	7.907 (17.440)	-2.819 (1.730)	-0.4081 (1.905)
VSL_{NIG}	$1,105,864	$488,740	$99,285

- $1.10 \preceq e \preceq 1.4$ which coincides with Miller (2000)
- Predictions match LDC VSL estimates in the sample
- Best meta-regresssion VSL prediction is 2a
- Comparing 2a and value transfer predictions, latter method underestimates VSL
    - Value transfer overlooks risk and study types in VSL studies
    - Best VSL is $488,000

Table 4: Mortality Costs of PM_{10} Pollution in Nigeria

	$b_{lower\ DRC,mortality}$	$b_{upper\ DRC,mortality}$
Mortality Cases	58,207	78,822

Table 5: Economic Costs of PM_{10} Pollution in Nigeria

	$b_{lowerDRC,mortality}$	$b_{upperDRC,mortality}$
Economic Cost (millions of US $)	28.46	38.54
Economic cost as a percentage of GDP	19.4	26.3

- Table presents a mortality related welfare loss of $28.5b - $38.5b
- Avoided at least 58,000 premature deaths and recorded an avoided mortality related welfare loss of $28.5b from the mitigation of PM_{10} polluton

Conclusion

- In the absence of local VSL estimates
  - Value transfer
  - Meta-regression Analysis
- Value transfer tends to underestimate VSL for LDCs
- Meta-regression approach better method and estimates VSL_{NIG} as $489,000
- Mitigation to WHO standard would have resulted in at least a decline in mortality by 58,000 people and earned a gross economic saving of at least $28.5b, equal to 19% of the nation's 2006 GDP
- Mitigation of particulate pollution stands to reap significant benefits for the nation - more healthy and productive labour force
- Estimate provided by this study is a conservative one because mortality effects of other air pollutants are not considered.

THANKS FOR LISTENING!