Housing Prices, Pollution, and Trends in the Value of a Statistical Life

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Summary

1. The Value of a Statistical Life (VSL)
2. Portney’s Approach
3. Gregor’s Study
4. Portney’s VSL for Allegheny County
5. Smith & Huang’s Meta-Study
6. iHAPSS MROD Data
7. VSL for Multiple Cities
8. Geographical variations in VSL
9. Conclusion
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3. **Gregor’s Study**  
   Model, data, aggregation
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Portney’s Approach – MWTP Data


Gives

\[
\frac{dV}{dQ}
\]

where

\[
V = \text{home sale price}
\]
\[
Q = \text{level of pollution (dust or SO}_2\text{)}
\]

Portney infers \(dV/dQ\) of \$59* per \(\mu g/m^3\) TSP

15% change in dustfall \(\rightarrow\) 15% change in TSP \(\rightarrow\) 18 \(\mu g/m^3\) change in TSP

* 2007 dollars
Portney’s Approach – MROD Data

EPA report by John Gregor (1977)

Gregor says there are three ways to get MROD data:

- Experiment
- Episodic studies
- Epidemiological studies

Are there increases in death due to pollution-related causes when the level of pollution increases?

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Independent Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardio/respiratory deaths</td>
<td>Education (proxy for income, insurance)</td>
</tr>
<tr>
<td>Other deaths</td>
<td>Population density</td>
</tr>
<tr>
<td>Total deaths</td>
<td>Temperature</td>
</tr>
<tr>
<td></td>
<td>Precipitation</td>
</tr>
<tr>
<td></td>
<td>TSP</td>
</tr>
<tr>
<td></td>
<td>SO$_2$</td>
</tr>
</tbody>
</table>

Gregor’s Study

Data from 1968-1972
By race, sex and age group
9% non-White in Allegheny County

<table>
<thead>
<tr>
<th>1970 Census</th>
<th>Population</th>
<th>% non-White</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pittsburgh</td>
<td>520,117</td>
<td>20.7%</td>
</tr>
<tr>
<td>Allegheny County</td>
<td>1,605,016</td>
<td>9.3%</td>
</tr>
<tr>
<td></td>
<td>excluding Pittsburgh</td>
<td>3.8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2000 Census</th>
<th>Population</th>
<th>% non-White</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pittsburgh</td>
<td>334,563</td>
<td>32.4%</td>
</tr>
<tr>
<td>Allegheny County</td>
<td>1,281,666</td>
<td>15.7%</td>
</tr>
<tr>
<td></td>
<td>excluding Pittsburgh</td>
<td>9.8%</td>
</tr>
</tbody>
</table>
Gregor’s Results

<table>
<thead>
<tr>
<th>White Population Only</th>
<th>Sex</th>
<th>Deaths per 100,000 per μg/m³ per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 45</td>
<td>Male</td>
<td>0.500</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0.349</td>
</tr>
<tr>
<td>45 – 64</td>
<td>Male</td>
<td>4.014</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1.570</td>
</tr>
<tr>
<td>65 and over</td>
<td>Male</td>
<td>10.291</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>9.541</td>
</tr>
</tbody>
</table>

For a household consisting of a 40-year-old couple with one male child

\[ MROD_{\text{household}} = \frac{0.500 + 0.349 + 0.500}{100,000} = 1.349 \times 10^{-5} \]
Portney’s Results

Household MWTP is the annual cost of \( \frac{dV}{dQ} \). Portney assumed a 10% interest rate, so

\[
MWTP = \rho \frac{dV}{dQ} = 0.10 \times \$59 = \$5.90
\]

Thus, for a household consisting of a 40-year-old couple with one male child

\[
VSL_{\text{household}} = \frac{MWTP}{MROD_{\text{household}}} = \frac{\$5.90}{1.349 \times 10^{-5}} = \$437k
\]

Note that, for a household consisting of a single 40-year-old male

\[
VSL_{\text{male} < 45} = \frac{MWTP}{MROD_{\text{male} < 45}} = \frac{\$5.90}{0.500 \times 10^{-5}} = \$1.18M
\]
## Gregor’s Results Revisited

<table>
<thead>
<tr>
<th>White Population Only</th>
<th>Sex</th>
<th>Deaths per 100,000 per μg/m³ per annum</th>
<th>% Population</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Under 45</strong></td>
<td>Male</td>
<td>0.500</td>
<td>31.66%</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0.349</td>
<td>32.81%</td>
</tr>
<tr>
<td><strong>45 – 64</strong></td>
<td>Male</td>
<td>4.014</td>
<td>11.76%</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1.570</td>
<td>13.06%</td>
</tr>
<tr>
<td><strong>65 and over</strong></td>
<td>Male</td>
<td>10.291</td>
<td>4.48%</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>9.541</td>
<td>6.22%</td>
</tr>
</tbody>
</table>

Weighted average = 2.000 deaths per 100,000 per μg/m³ per annum

\[ VSL_{random} = \frac{$5.90}{2.000 \times 10^{-5}} = $295k \]
Smith-Huang Meta-Study

37 hedonic housing studies between 1964 and 1978 yielding $dV/dQ$. Developed an econometric model of $dV/dQ$ with independent variables:

- TSP
- Income
- Vacancy
- # of neighborhood characteristics in hedonic model
- # of air pollution variables in hedonic model
- Actual price flag
- Linear model flag
- Semilog model flag
- Log-linear model flag
- OLS estimator flag
- Census 1960 vs. Census 1970
- Year
- Unpublished flag
- Inverse mills ratio

Meta-model: MWTP for Pittsburgh $124.50 per $\mu g/m^3$

Health Effects Institute


NMMAPS (National Morbidity, Mortality, and Air Pollution Study) – 1996 - 2000. 20, then 90 cities.
- co-pollutant correlation \((TSP, SO_2, O_3)\)
- measurement error
- exposure error
- mortality displacement
- TSP \(\rightarrow\) PM10 \((14\text{ cities})\)

Joined by Schwartz, Dockery, and Francesca Dominici

Time-series issues
NMMAPS grew into iHAPSS - the Internet-based Health and Air Pollution Surveillance System, which was funded by HEI and hosted at Johns Hopkins.

Eventually included the 100 largest US cities.

Log-linear model of mortality as a function of DOW, time, temp over multiple time-scales, humidity over multiple time scales, age, with multiple time-scale smoothing.

For Pittsburgh:

\[
MROD = \frac{0.2189}{100} \times \frac{746}{100,000} = 1.633 \times 10^{-7} \text{ per } \mu g/m^3 \text{ PM}_{10}
\]

\[
= 0.60 \times 1.633 \times 10^{-7} = 9.80 \times 10^{-8} \text{ per } \mu g/m^3 \text{ TSP}
\]

Smith-Huang Meta-Study

18 studies over 9 metropolitan areas for which there are iHAPSS data:

- Boston, Chicago, Kansas City, Los Angeles, Milwaukee, New York, San Francisco, St Louis, and Washington

4 Composite studies

**Brookshire et al (1979)** Los Angeles and Orange counties

**Palmquist (1982)** Minneapolis, Houston, Dallas, San Francisco, Miami, Los Angeles, Portland, Chicago, Philadelphia, Atlanta, Anaheim, Washington, Cincinnati, San Bernardino, Indianapolis, St. Louis, Baltimore, Detroit, Denver, Tacoma

**Palmquist (1983)** Chicago, Los Angeles, Philadelphia, San Bernardino, Portland, Denver, Detroit, Dallas, Washington, Indianapolis

**Palmquist (1984)** Miami, Houston, Atlanta, Denver, Seattle, Louisville, Oklahoma City
The Value of a Statistical Life (VSL)

$1.94M

Present value of lifetime earnings

2007 dollars
The Value of a Statistical Life (VSL)

$1.94M

$452k to $1.24M

WTA High-Risk Occupations
Thaler & Rosen (1975)

2007 dollars
The Value of a Statistical Life (VSL)

- Present value of lifetime earnings
  - Dargis (1989)
  - WTP
  - WTA
  - High-Risk Occupations
  - Thaler & Rosen (1975)

$1.94M

$452k to $1.24M

$0.9M

2007 dollars
The Value of a Statistical Life (VSL)

Housing Prices for Reduced Air Pollution (Portney 1984)

$437k

$1.94M

$452k to $1.24M

WTA High-Risk Occupations (Thaler & Rosen 1975)

2007 dollars
The Value of a Statistical Life (VSL)

WTP Housing Prices for Reduced Air Pollution (Portney, 1981)

WTP Smoke Detectors (Garbacz, 1989)

WTP Automobile Safety

Dreyfus & Viscusi (1995)

WTP Safety Belts, Car Seats and Motorcycle Helmets

Bromquist, Miller & LeM (1996)

$1.94M

$1.4M to $5.2M

$4.6M to $6.5M

$2.0M to $11.9M

$452k to $1.24M

$1.24M

$6.2M


2007 dollars
Portney’s Approach – Historical Context

1930 -1970 Flight to the suburbs
1970 -2008 Flight from the Rust Belt

Paul R. Portney, 1981, *Housing prices, health effect and valuing reductions in risk of death.* JEEM 8(72)
Portney’s Approach

The marginal risk of death (MROD) is the increase in the risk of death resulting from a $1 \mu g/m^3$ increase in total suspended particles (TSP).

Or, MROD is the decrease in the risk of death resulting from a $1 \mu g/m^3$ reduction in TSP. Inverting this gives us the population for which one statistical life is saved.

The home purchase decision of a household reflects the WTP for reduced ROD for all members of household. That is, they want to decrease the probability that any member of the household die from air pollution.

$$\frac{1}{MROD_{\text{household}}} = \text{Number of households in which one statistical life is saved}$$
VSL for Multiple Cities

- Boston: 1.31
- Chicago: 0.00, 0.00, 75.92
- Kansas City: 4.99
- Los Angeles: 44.81, 40.36
- Milwaukee: 27.23
- New York: 2.66
- Palmquist (83): 2.32
- Palmquist (82): 22.13
- Palmquist (84): 22.13
- San Francisco: 110.01
- SoCal Air Basin: 4.58
- St. Louis: 3.09
- Washington: 10.00, 11.13
- Total (all cities): 406.07

Millions of 2007 dollars
VSL for Multiple Cities – Econometric Models

Model 1
\[ VSL = b_0 + b_1 \text{ (median household income)} \]

Model 2
\[ VSL = b_0 + b_2 \text{ (population)} \]

Model 3
\[ VSL = b_0 + b_3 \text{ (risk of death)} \]

Model 4
\[ VSL = b + b_1 \text{ (median household income)} + b_2 \text{ (population)} + b_3 \text{ (risk of death)} \]
VSL for Multiple Cities – Zero Intercept Econometric Models

Model 5

\[ VSL = b_1 \text{ (median household income) } \]

Model 6

\[ VSL = b_2 \text{ (population) } \]

Model 7

\[ VSL = b_3 \text{ (risk of death) } \]

Model 8

\[ VSL = b_1 \text{ (median household income) } + b_2 \text{ (population) } + b_3 \text{ (risk of death) } \]
VSL for Multiple Cities – Results

<table>
<thead>
<tr>
<th>Model</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant std.err.</td>
<td>−69.247</td>
<td>44.458</td>
<td>66.139</td>
<td>−80.379</td>
</tr>
<tr>
<td></td>
<td>80.731</td>
<td>13.653</td>
<td>47.755</td>
<td>182.500</td>
</tr>
<tr>
<td>Income ($millions) std.err.</td>
<td>2090.734</td>
<td>1549.279</td>
<td>2558.065</td>
<td>2298.650</td>
</tr>
<tr>
<td>Population (millions) std.err.</td>
<td>−0.756</td>
<td>1.050</td>
<td>−1.274</td>
<td>1.229</td>
</tr>
<tr>
<td>R²</td>
<td>0.084</td>
<td>0.025</td>
<td>0.017</td>
<td>0.147</td>
</tr>
<tr>
<td>adjusted R²</td>
<td>0.038</td>
<td>−0.024</td>
<td>−0.032</td>
<td>0.005</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income ($millions) std.err.</td>
<td>773.677</td>
<td>205.134</td>
<td>1601.538</td>
<td>736.942</td>
</tr>
<tr>
<td>Population (millions) std.err.</td>
<td>1.237</td>
<td>1.030</td>
<td>−1.462</td>
<td>1.128</td>
</tr>
<tr>
<td>R²</td>
<td>0.404</td>
<td>0.064</td>
<td>0.324</td>
<td>0.459</td>
</tr>
<tr>
<td>adjusted R²</td>
<td>0.375</td>
<td>0.020</td>
<td>0.292</td>
<td>0.374</td>
</tr>
</tbody>
</table>

** 95 percent confidence
*** 99 percent confidence
VSL for Multiple Cities – Discussion

Whence the multiplier 774?

Mean Homeowner Income

Mean Income 31.2% higher than Median Income
Homeowner Income 11.7% higher than Median Income

Value of Leisure

$1.66M present value lifetime earnings based on median income implying a VSL of $16M to $33M. (Keeler 2001)

Together

The range is $23M to $48 assuming homeowner mean income. 1990 U.S. metropolitan median income was $53,584 (2007 dollars) Multiplier between 438 and 903.

Future Value

9.37% over 48 years
Appendices
Present Value of Lifetime Earnings

Figure 3. Synthetic Work-Life Earnings Estimates for Full-Time, Year-Round Workers by Educational Attainment Based on 1997-1999 Work Experience

(In millions of 1999 dollars)

- Doctoral degree: $3.4
- Professional degree: $4.4
- Master’s degree: $2.5
- Bachelor’s degree: $2.1
- Associate’s degree: $1.6
- Some college: $1.5
- High school graduate: $1.2
- Not high school graduate: $1.0


Census Bureau, *The Big Payoff: Educational Attainment and Synthetic Estimates of Work-Life Earnings*
Present Value of Lifetime Earnings (2)

- High school graduate, 31.48%
- Bachelor's degree, 17.48%
- Associate's degree, 8.19%
- Some college, 19.01%
- Master's degree, 6.18%
- Doctoral degree, 1.12%
- Professional degree, 1.40%
- Not high school graduate, 15.14%

2007 population by degree status
# Present Value of Lifetime Earnings (3)

<table>
<thead>
<tr>
<th>Degree</th>
<th>1994 SWE ($M)</th>
<th>2007 ($M)</th>
<th>Population fraction</th>
<th>Contribution ($M 2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctoral degree</td>
<td>3.4</td>
<td>4.2</td>
<td>1.12%</td>
<td>0.05</td>
</tr>
<tr>
<td>Professional degree</td>
<td>4.4</td>
<td>5.5</td>
<td>1.40%</td>
<td>0.08</td>
</tr>
<tr>
<td>Master's degree</td>
<td>2.5</td>
<td>3.1</td>
<td>6.18%</td>
<td>0.19</td>
</tr>
<tr>
<td>Bachelor's degree</td>
<td>2.1</td>
<td>2.6</td>
<td>17.48%</td>
<td>0.45</td>
</tr>
<tr>
<td>Associate's degree</td>
<td>1.6</td>
<td>2.0</td>
<td>8.19%</td>
<td>0.16</td>
</tr>
<tr>
<td>Some college</td>
<td>1.5</td>
<td>1.9</td>
<td>19.01%</td>
<td>0.36</td>
</tr>
<tr>
<td>High school graduate</td>
<td>1.2</td>
<td>1.5</td>
<td>31.48%</td>
<td>0.47</td>
</tr>
<tr>
<td>Not high school graduate</td>
<td>1.0</td>
<td>1.2</td>
<td>15.14%</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Average SWE ($M 2007) 1.94

BLS inflator 1999-2007: 1.2446

SWE = synthetic work-life earnings
Portney’s Approach – Household MROD

The probability of at least one member of the household dying is

\[ ROD_{\text{household}} = 1 - \sum_{i}^{N} (1 - ROD_i) \]

\[ N = \text{number in household} \]

The marginal probability is

\[ MROD_{\text{household}} = \sum_{j}^{N} MROD_j \sum_{i \neq j}^{N} (1 - ROD_i) \]

So, for small \( N \)

\[ MROD_{\text{household}} \approx \sum_{j}^{N} MROD_j \]
Portney’s Approach – Calculating the VSL

The number of households for which one statistical life is saved with a 1 $\mu g/m^3$ reduction of TSP is

$$P_{\text{households}} = \frac{1}{MROD_{\text{household}}}$$

If these households have an average WTP for a 1 $\mu g/m^3$ reduction in TSP, then their aggregate marginal willingness to pay (MWTP) is the value of the statistical life saved. That is

$$VSL = MWTP \times P_{\text{household}}$$

Or

$$VSL = \frac{MWTP}{MROD_{\text{household}}}$$