Environmental Benefit Cost Analysis and The National Accounts.

N. Z. Muller

Middlebury College, NBER

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  - Benefit Cost Analysis (BCA) is a common tool for policy evaluation.
- Effects on GDP common way to gauge policy (CBO, 2013).
- Do conventional measures of performance (GDP) reflect policy?
  - Overlap between market indicators and BCA depend on policy context.
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- Conducts a rudimentary BCA focusing on adoption of flue gas desulfurization (FGD) technology between 2005 and 2011.
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- Argues that incentives embodied in Clean Air Act (broadly, air pollution policy) yield FGD installation.
- Compares EVA growth to GDP growth, by state, with and without FGD.
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Trends in flue gas desulfurization: EGUs in the U.S.
Outline of the Talk.

- Methods:
  - Conceptual Model.
  - Empirical Model.
- Results.
- Conclusions
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Comparing Annual Rates of Change in VA, EVA, and GED.

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- Augmented Accounts
- Valuation
- Dose-Response
- Emissions
- Air Quality Model
- Ambient Concentration
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  - Premature mortality: VSL $6$ million (USEPA, 1999).
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- Repeat across other sources adding scrubbers, and over 2008, 2011 data years.
Empirical Model: PM2.5 Ambient Concentration.
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Empirical Model: Marginal damages PM2.5 at RE Burger.

Atlantic Ocean Forest Recreation Damages by County ($ x 1,000)

Change PM2.5 (ug/m^3)

0
0 - 0.0001
0.0001 - 0.0005
0.0005 - 0.001
0.001 - 0.002
0.002 - 0.007

Atlantic
Empirical Model: Marginal damages PM2.5 at RE Burger.
Empirical Model: SO2 Marginal damages.

Damage ($/ton)
- 0 - 500
- 500 - 1,000
- 1,000 - 2,500
- 2,500 - 5,000
- 5,000 - 7,500
- 7,500 - 15,000
- 15,000 - 57,000

Map showing damages by county ($x1,000) across the United States.
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<tbody>
<tr>
<td>GED (Air Pollution)$^A$</td>
<td>0.06</td>
<td>0.05</td>
<td>0.04</td>
<td>0.03</td>
<td>0.02</td>
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<tr>
<td>GED (Air Pollution, GHG$^B$)</td>
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<tr>
<td>GED (Air Pollution, GHG - 95$^{th}$)$^C$</td>
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<td>1.5</td>
<td>2.4</td>
</tr>
</tbody>
</table>

A = Results from 1999 - 2008 reported in Muller (2014a)
B = Social cost of carbon value if $28/ton \ CO_2$ (OMB, 2013)
C = Social cost of carbon value if $78/ton \ CO_2$ (OMB, 2013)
Utility Sector: Real EVA, VA, and GED.

![Graph showing trends in EVA, VA, and GED over the years 1999 to 2011.](image)
## Costs and Benefits of FGD Installation: 2008 to 2011

<table>
<thead>
<tr>
<th>State</th>
<th>Cost</th>
<th>GED</th>
<th>GED (No FGD)</th>
<th>Benefit</th>
<th>$B/C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Jersey</td>
<td>3</td>
<td>24</td>
<td>131</td>
<td>107</td>
<td>39:1</td>
</tr>
<tr>
<td>Delaware</td>
<td>0</td>
<td>154</td>
<td>161</td>
<td>7</td>
<td>33:1</td>
</tr>
<tr>
<td>Ohio</td>
<td>24</td>
<td>2,080</td>
<td>2,830</td>
<td>742</td>
<td>31:1</td>
</tr>
<tr>
<td>North Carolina</td>
<td>30</td>
<td>132</td>
<td>1,030</td>
<td>903</td>
<td>30:1</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>192</td>
<td>1,090</td>
<td>6,350</td>
<td>5,260</td>
<td>27:1</td>
</tr>
<tr>
<td>National (30 States)</td>
<td>892$^A$</td>
<td>8,700</td>
<td>28,470</td>
<td>19,770</td>
<td>22:1</td>
</tr>
</tbody>
</table>

$A =$ All values expressed in real $millions, "high" cost scenario
Change in PM2.5 Due to FGD Installation: 2011.

- Change PM2.5 (ug.m$^3$)
  - 0.00 - 0.05
  - 0.06 - 0.10
  - 0.11 - 0.25
  - 0.26 - 0.50
  - 0.51 - 0.72
  - 0.73 - 1.00
  - 1.01 - 1.10

[Map showing changes in PM2.5 across the United States]
Change in Damage Due to FGD Installation: 2011.
FGD Installation and GDP, GED, and EVA Growth from 2008 to 2011.

<table>
<thead>
<tr>
<th>State</th>
<th>GDP</th>
<th>GED</th>
<th>GED (No FGD)</th>
<th>EVA (No FGD)</th>
<th>Diff. EVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Virginia</td>
<td>4.24</td>
<td>-16.72</td>
<td>-4.81</td>
<td>6.86</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(5.65)</td>
<td></td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>1.72</td>
<td>-13.81</td>
<td>-7.75</td>
<td>2.61</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.33)</td>
<td></td>
</tr>
<tr>
<td>North Dakota</td>
<td>5.48</td>
<td>3.44</td>
<td>6.24</td>
<td>5.66</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(5.42)</td>
<td></td>
</tr>
<tr>
<td>Kentucky</td>
<td>2.19</td>
<td>-4.91</td>
<td>-1.11</td>
<td>2.68</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.44)</td>
<td></td>
</tr>
<tr>
<td>Maryland</td>
<td>1.76</td>
<td>-12.84</td>
<td>-4.99</td>
<td>2.22</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.01)</td>
<td></td>
</tr>
<tr>
<td>National (30 States)</td>
<td>1.08 (^A)</td>
<td>-5.78</td>
<td>-3.58</td>
<td>1.27</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(1.21)</td>
<td></td>
</tr>
</tbody>
</table>

A = Annual rates of change (%).
Observed and No-Scrub Counterfactual: West Virginia.
Fraction of Benefits Occurring In-State 2011.
## EVA Growth between 2008 to 2011 with In-State Benefits.

<table>
<thead>
<tr>
<th>State</th>
<th>Total Benefits</th>
<th>In-State Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EVA (No FGD)</td>
<td>Diff. EVA</td>
</tr>
<tr>
<td>National (30 States)</td>
<td>1.27 (1.21)</td>
<td>0.06</td>
</tr>
<tr>
<td>West Virginia</td>
<td>6.86 (5.65)</td>
<td>1.20</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>2.61 (2.33)</td>
<td>0.28</td>
</tr>
<tr>
<td>North Dakota</td>
<td>5.66 (5.42)</td>
<td>0.24</td>
</tr>
<tr>
<td>Kentucky</td>
<td>2.68 (2.44)</td>
<td>0.24</td>
</tr>
</tbody>
</table>

A = Annual rates of change (%).
Change in Ambient Concentration and County Demographics: 2011.
Benefit Per Capita and County Demographics: 2011.

The graph shows the distribution of benefits per capita among different racial groups. The x-axis represents different racial categories: All, White, Afr. Amer., Asian, and Hisp. The y-axis represents the benefit per capita in dollars. The data indicates variability in benefits across these categories, with Afr. Amer. and Asian groups showing notably higher benefits compared to others.
Change in Ambient Concentration and County Income: 2011.
Outline of the Talk.

- Methods:
  - Conceptual Model.
  - Empirical Model.

- Results.

- Conclusions.
Conclusions.

- Measurement important during macroeconomic shocks.
**Conclusions.**

- Measurement important during macroeconomic shocks.
  - Inclusive of private sector output and public policy evaluation (BCA).

**Finding:**

- FGD investment enhances growth.
  - In 30 States with new FGD between 2008 and 2011: EVA (+) 0.06% with FGD.
  - West Virginia state EVA (+) 1.2% with FGD; PA, ND, KY (+) 0.25% with FGD.

**Caveats:** External validity and causation.
Conclusions.

- Measurement important during macroeconomic shocks.
  - Inclusive of private sector output and public policy evaluation (BCA).
- Common for policymakers and stakeholders to frame policy effects in terms of GDP.

Finding: FGD investment enhances growth.

In 30 States with new FGD between 2008 and 2011: EVA (+) 0.06\% with FGD.

West Virginia state EVA (+) 1.2\% with FGD; PA, ND, KY (+) 0.25\% with FGD.

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Finding:
FGD investment enhances growth.
In 30 States with new FGD between 2008 and 2011: EVA (+) 0.06% with FGD.
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Conclusions.

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Caveats: External validity and causation.
Conclusions.

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  - Inclusive of private sector output and public policy evaluation (BCA).
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  - GDP likely biased in environmental context: externality.
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  - **Finding**: FGD investment enhances growth.
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Conclusions.

- Measurement important during macroeconomic shocks.
  - Inclusive of private sector output and public policy evaluation (BCA).
- Common for policymakers and stakeholders to frame policy effects in terms of GDP.
  - GDP likely biased in environmental context: externality.
- Essential to assess growth based on an index inclusive of both benefits and costs.
  - **Finding:** FGD investment enhances growth.
    - In 30 States with new FGD between 2008 and 2011: EVA (+) 0.06% with FGD.
    - West Virginia state EVA (+) 1.2% with FGD; PA, ND, KY (+) 0.25% with FGD.
- Caveats: External validity and causation.
Conceptual Model.
Marginal Damage Functions for SO2.

- TVA Johnsonville (600ft.)
- TVA Johnsonville (0ft.)
- Nashville, TN (0ft.)
- New York City (0ft.)
Chart 1. Percent Change in Real GDP by State, 2006-2007
Empirical Model

\[ \rho = 0.86 \]

Model Sulfate (ug/m³)

Monitor Sulfate (ug/m³)

USEPA AIRS, IMPROVE 2011
Marginal Damage for Sulfur Dioxide.

<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>mean</th>
<th>sd</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Base</td>
<td>10,980$^A$</td>
<td>3,209</td>
<td>3,158</td>
<td>16,154</td>
</tr>
<tr>
<td>2011</td>
<td>Base</td>
<td>11,534$^B$</td>
<td>5,996</td>
<td>948</td>
<td>38,832</td>
</tr>
<tr>
<td>2008</td>
<td>Roman</td>
<td>17,583</td>
<td>5,031</td>
<td>4,967</td>
<td>25,430</td>
</tr>
<tr>
<td>2011</td>
<td>Roman</td>
<td>18,384</td>
<td>9,470</td>
<td>1,493</td>
<td>61,204</td>
</tr>
<tr>
<td>2008</td>
<td>$2M$ VSL</td>
<td>4,373</td>
<td>1,213</td>
<td>1,329</td>
<td>6,278</td>
</tr>
<tr>
<td>2011</td>
<td>$2M$ VSL</td>
<td>4,638</td>
<td>2,389</td>
<td>425</td>
<td>15,291</td>
</tr>
</tbody>
</table>

$A = (\$/\text{ton})$, for plants installing scrubbers between 2005 and 2008.  
$B = (\$/\text{ton})$, for plants installing scrubbers between 2008 and 2011.
All Sectors: Regional Rates of Growth and Pollution Intensity.

<table>
<thead>
<tr>
<th>Region</th>
<th>1999-2011</th>
<th>GED/GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GED</td>
<td>EVA</td>
</tr>
<tr>
<td>New England</td>
<td>-9.35&lt;sup&gt;A&lt;/sup&gt;</td>
<td>1.79</td>
</tr>
<tr>
<td>Mideast</td>
<td>-8.08</td>
<td>2.34</td>
</tr>
<tr>
<td>Southeast</td>
<td>-7.61</td>
<td>2.32</td>
</tr>
<tr>
<td>Great Lakes</td>
<td>-6.54</td>
<td>1.32</td>
</tr>
<tr>
<td>Plains</td>
<td>-3.80</td>
<td>2.41</td>
</tr>
<tr>
<td>Rocky Mountains</td>
<td>-4.12</td>
<td>2.96</td>
</tr>
<tr>
<td>Southwest</td>
<td>-3.49</td>
<td>3.52</td>
</tr>
<tr>
<td>Far West</td>
<td>-4.45</td>
<td>2.07</td>
</tr>
<tr>
<td>National</td>
<td>-6.63</td>
<td>2.32</td>
</tr>
</tbody>
</table>

<sup>A</sup> = Annualized rates of change (%).
### Benefit Incidence and County Demographics: 2011.

<table>
<thead>
<tr>
<th>Race</th>
<th>PM$_{2.5}$ % Change</th>
<th>PM$_{2.5}$ Abs. Change</th>
<th>Monetary Benefit % Change</th>
<th>Monetary Benefit Abs. Change</th>
<th>Benefit/Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Counties</td>
<td>-4.5 (4.2)</td>
<td>-0.4$^A$ (0.3)$^B$</td>
<td>-4.2 (3.9)</td>
<td>11.7$^C$ (35.0)</td>
<td>125.6 (122.4)</td>
</tr>
<tr>
<td>White</td>
<td>-4.2 (4.3)</td>
<td>-0.3 (0.3)</td>
<td>-4.0 (4.0)</td>
<td>7.2 (20.9)</td>
<td>119.0 (127.6)</td>
</tr>
<tr>
<td>Afr. American</td>
<td>-5.5 (3.7)</td>
<td>-0.5 (0.3)</td>
<td>-5.1 (3.5)</td>
<td>22.7 (53.2)</td>
<td>158.7 (105.0)</td>
</tr>
<tr>
<td>Asian American</td>
<td>-4.8 (4.7)</td>
<td>-0.4 (0.4)</td>
<td>-4.4 (4.4)</td>
<td>34.3 (65.8)</td>
<td>116.8 (118.3)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>-2.8 (3.4)</td>
<td>-0.2 (0.3)</td>
<td>-2.6 (3.2)</td>
<td>16.9 (51.1)</td>
<td>66.7 (90.2)</td>
</tr>
</tbody>
</table>

$A = \frac{ug}{m^3}$.

$B = $ standard deviations in parenthesis.

$C = ($ millions).
### All Sectors: State Rates of Growth and Pollution Intensity

<table>
<thead>
<tr>
<th>State</th>
<th>GED</th>
<th>EVA</th>
<th>GDP</th>
<th>EVA-GDP</th>
<th>1999</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Virginia</td>
<td>-11.87(^A)</td>
<td>5.68</td>
<td>2.30</td>
<td>3.38</td>
<td>0.364</td>
<td>0.061</td>
</tr>
<tr>
<td>North Dakota</td>
<td>-5.17</td>
<td>7.66</td>
<td>5.48</td>
<td>2.18</td>
<td>0.277</td>
<td>0.078</td>
</tr>
<tr>
<td>Wyoming</td>
<td>-4.29</td>
<td>7.91</td>
<td>6.89</td>
<td>1.03</td>
<td>0.142</td>
<td>0.038</td>
</tr>
<tr>
<td>Kentucky</td>
<td>-7.22</td>
<td>2.10</td>
<td>1.17</td>
<td>0.93</td>
<td>0.152</td>
<td>0.054</td>
</tr>
<tr>
<td>Indiana</td>
<td>-6.35</td>
<td>1.82</td>
<td>1.55</td>
<td>0.88</td>
<td>0.149</td>
<td>0.056</td>
</tr>
<tr>
<td>National</td>
<td>-6.33</td>
<td>2.32</td>
<td>1.96</td>
<td>0.36</td>
<td>0.064</td>
<td>0.023</td>
</tr>
</tbody>
</table>

\(^A\) = Annualized rates of change (%).
Utility Sector: Rates of Growth and Pollution Intensity.

<table>
<thead>
<tr>
<th>Region</th>
<th>1999-2011</th>
<th>GED/VA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GED</td>
<td>EVA</td>
</tr>
<tr>
<td>New England</td>
<td>-11.49^A</td>
<td>1.40</td>
</tr>
<tr>
<td>Mideast</td>
<td>-10.11</td>
<td>7.04</td>
</tr>
<tr>
<td>Southeast</td>
<td>-10.20</td>
<td>B</td>
</tr>
<tr>
<td>Great Lakes</td>
<td>-7.83</td>
<td>B</td>
</tr>
<tr>
<td>Plains</td>
<td>-5.22</td>
<td>8.79</td>
</tr>
<tr>
<td>Rocky Mountains</td>
<td>-2.97</td>
<td>0.99</td>
</tr>
<tr>
<td>Southwest</td>
<td>-5.07</td>
<td>3.60</td>
</tr>
<tr>
<td>Far West</td>
<td>-5.70</td>
<td>0.68</td>
</tr>
<tr>
<td>National</td>
<td>-5.75</td>
<td>16.06</td>
</tr>
</tbody>
</table>

^A = Annualized rates of change (%).
B = EVA changes sign from 1999 to 2011. No growth rate reported.
Empirical Model: Comparison of Monitor Data and APEEP Prediction (PM2.5).

\[ Y = -1.16 + 0.804(PM_{2.5}) \]

\[ R^2 = 0.38 \]

Source: Muller, 2011
Empirical Model: Comparison of Monitor Data and APEEP Prediction (Ammonium Sulfate).

\[ Y = -0.199 + 0.676(SO_4). \quad R^2 = 0.67 \]

Source: Muller, 2011
Empirical Model: Comparison of Monitor Data and APEEP Prediction (Ozone).

\[ Y = 20.44 + 0.490(O_3). \quad R^2 = 0.60 \]

<table>
<thead>
<tr>
<th>Pollutant/Species</th>
<th>MFE</th>
<th>MFB</th>
<th>Rho</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total PM$_{2.5}$</td>
<td>0.072</td>
<td>-0.016</td>
<td>0.63</td>
<td>673</td>
</tr>
<tr>
<td>Ammonium Sulfate</td>
<td>0.105</td>
<td>0.013</td>
<td>0.87</td>
<td>153</td>
</tr>
<tr>
<td>Ammonium Nitrate</td>
<td>0.245</td>
<td>-0.067</td>
<td>0.50</td>
<td>153</td>
</tr>
<tr>
<td>Organic Carbon</td>
<td>0.130</td>
<td>0.084</td>
<td>0.37</td>
<td>153</td>
</tr>
<tr>
<td>Elemental Carbon</td>
<td>0.100</td>
<td>0.011</td>
<td>0.66</td>
<td>153</td>
</tr>
</tbody>
</table>

Source: Muller, 2011; USEPA AIRS, 2011; AQS IMPROVE, 2011
Boylan, Russell, 2006: MFE $\leq$ 50%, MFB $\leq$ 30%.