A Hedonic Analysis of Water Quality and the Chesapeake Bay TMDL

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June 2014 – NAREA Annual Conference

Disclaimer: The views presented here do not necessarily represent the views of the EPA.
Chesapeake Bay

• Largest estuary in the US
• Drainage basin covers 6 states: NY, PA, DE, MD, VA, WV, as well as DC
• Watershed home to more than 17 million people
Chesapeake Bay Pollution

• Site of one of the planet’s first recognized “dead zones”
  – Fish kills and other problems
  – Estimated to now kill thousands of tons of clams, fish, and worms annually

• Large nutrient inputs cause a range of issues, including algal blooms, toxic algae, poor water quality.
  – Each year, roughly 300 million lbs of nitrogen reaches the Bay, about six times the amount in the 1600’s.

• Colonial times – estimated 200,000 acres of oyster reefs. Today only 36,000.

• Estimated 100,000 new residents in the watershed each year.
Chesapeake Bay TMDL

• Extensive restoration efforts over last 25 years
  – Insufficient progress
  – Continued poor water quality
  – PA, NY Farming inputs.

• Dec 29, 2010: Chesapeake Bay Total Maximum Daily Load (TMDL) – historic and comprehensive “pollution diet”.
  – Specifically, the TMDL sets Bay nitrogen (25%), phosphorus (24%) sediment (20%) reductions.

• “Novelty”: comprehensive involvement of all state actors in the watershed
  – Using extensive modeling tools and planning coordinated by EPA
Chesapeake Bay TMDL Valuation

• In 2011, EPA committed to an assessment of the benefits and costs of the TMDL.

• NCEE, and Chesapeake Bay Program Office (CBPO).
  – SP Survey
  – Commercial and recreational fishing
  – Air Quality Impacts
  – Property price benefits
  – Dredging and several other categories
  – Costs
Property Prices

• Recreational and aesthetic improvements from the TMDL may be reflected in nearby property prices.
• Hedonic analysis of water quality in 14 MD counties
• Peer Review
  – Input from three academics with experience in hedonics of water quality/ecosystem services/coastal resources.
Hedonic Water Quality Literature

- Literature is somewhat thin, particularly compared to air quality
- Majority from the northeastern US, in Lakes
  - Three recent studies in Florida, one on a Bay/Lagoon (Bin and Czajkowski).
- Chesapeake Bay – Leggett and Bockstael (2000), Poor et al. (2007)
- Multiple water quality indicators have been used
  - Oil content, turbidity (Feenberg and Mills, 1980) Fecal Coliform (Leggett and Bockstael, 2000), survey responses (Michael et al., 2000), Inorganic Nitrogen (Poor et al., 2007), TN, TP, CH (Walsh et al., 2011) “Location grade” (Bin and Czajkowski, 2013), several others.
- Water clarity is the most prevalent in the literature
  - Easily perceived, usually good representation of “quality.”
- Majority of studies find a significant relationship between water quality and home prices.
Water Quality Indicator

• Select $K_D$, the light attenuation coefficient
  – Clarity: $K_D = 1.45/SDM$
  – Good historical data
  – CBPO’s water quality model: project scenarios
    • TMDL vs baseline

• Chesapeake Bay has water quality criteria for clarity.
  – SP survey
• 14 Maryland Counties
Property Data

• Full set of parcels/sales from 1996-2008 from MD PropertyView

• GIS Maps
  – Census, waterbodies, zoning, open space
Data

• Water Quality
  – Interpolate historical data from monitoring stations
    • CBPO – WQ -> Interpolator cells
      – Approximately 1 km X 1 km

• GIS, Census data
  – High or medium density area, forest, etc
  – Open space, ag., wetlands, beaches
  – Dist to primary road, dist to nearest beach
  – Dist to DC or Baltimore
  – Block Group socioeconomic characteristics
  – In Nuclear Evacuation Zone.
  – Within 2 miles of power plant.
Methods

• Distance buffers

\[ \ln(P) = \beta_0 + \beta_{WF} \cdot WF + \beta_{WF2} \cdot \ln(WQ) \cdot WF + \sum \beta_{Di} \cdot \ln(WQ_i) \cdot Dist_i + \beta_{D2} \cdot Dist + \beta_H \cdot H + \beta_L \cdot L + \beta_T \cdot T + \varepsilon \]

– WF, 0-500, 500-1000, 1000-1500, 1500-2000

• Regressions estimated for each county
  – Separate markets
... Other Alternatives

• Several others, some later explored in Meta-analysis.
  – Water quality not logged
  – 3 year water quality average, logged and not logged
  – Depth variable
  – Chlorophyll
Spatial Models

• Spatial dependence
  – Spatially correlated unobserved influences
  – Can cause bias or inconsistency in the estimated coefficients.

• Spatial Weights Matrix
  – Exogenously specify the neighborhood.
    • Nearest neighbor, Inverse Distance
      – Comparable sales

• General Spatial Model:
  \[ y = \rho W_1 y + X \beta + \epsilon, \quad \epsilon = \lambda W_2 \epsilon + u \]
<table>
<thead>
<tr>
<th></th>
<th>Bayfront</th>
<th>0-500 meters</th>
<th>500-1000 meters</th>
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<tbody>
<tr>
<td>Anne Arundel</td>
<td>-0.126***</td>
<td>-0.023***</td>
<td>-0.009</td>
</tr>
<tr>
<td>Baltimore County</td>
<td>-0.090***</td>
<td>0.009</td>
<td>-0.015*</td>
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<tr>
<td>Calvert</td>
<td>-0.033*</td>
<td>0.001</td>
<td>0.021*</td>
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<tr>
<td>Cecil</td>
<td>0.010</td>
<td>-0.001</td>
<td>0.003</td>
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<tr>
<td>Charles</td>
<td>-0.058</td>
<td>-0.056**</td>
<td>-0.107***</td>
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<tr>
<td>Dorchester</td>
<td>-0.078*</td>
<td>-0.008</td>
<td>-0.013295</td>
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<tr>
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<td>Kent</td>
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<td>Prince Georges</td>
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<td>0.022**</td>
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<td>Queen Annes</td>
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<td>-0.060***</td>
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<tr>
<td>Somerset</td>
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<td>-0.055</td>
<td>-0.141***</td>
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<td>St Marys</td>
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<td>-0.015</td>
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<td>Talbot</td>
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<td>-0.014</td>
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<td>Wicomico</td>
<td>0.046</td>
<td>-0.015</td>
<td>-0.010</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1
Overall results

- Across the 14 counties:
  - 10 of 14 have negative waterfront coefficient
    - $K_D$ and clarity inversely related
    - 7 of which are significant
  - None of the positive waterfront coefficients are significant
  - Mixed results beyond the waterfront
    - Evidence of impacts extending out past 500m in some counties.
Temporal Consistency?

• Length of data – questions about temporal consistency of estimates
• Identified several time demarcations to split the data
  – Run regressions on:
    • 1996-2001
    • 1996-2005
    • 2002-2008
    • 2002-2005
    • 2006-2008
• Results were mostly consistent across specifications, with minor differences in magnitude
  – Main difference: 2006-2008 data.
    • Larger variation in magnitude of the implicit prices.
    • However, when full model compared to 1996-2005, adding 2006-2008 did not appreciably change results.
Other Project Components

- Meta-analysis of 14 Counties, specifications
Appendix 1: Sales over time

- **Total # of Sales**

- **Total # of WF sales**
Appendix 2

- Percent of Vacant Sales across Counties