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Uncertainty Analysis Plan for the Second Section 812 Prospective Study of Benefits and Costs of the Clean Air Act

Briefing for SAB Advisory Council on Clean Air Act Compliance Analysis

Henry Roman
Senior Associate
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INDUSTRIAL ECONOMICS, INCORPORATED

Outline

- Background
- Objectives
- Overview of Plan
  - Scenario Analysis
  - Expanded Benefits Uncertainty Analysis
  - Offline Uncertainty Analyses
  - Enhanced Presentation Tools
- Next Steps

Background

- Approach to uncertainty analysis in First Prospective 812 Study
  - Quantitative assessment limited to health outcomes and valuation; extensive qualitative assessment (summary tables)
- SAB encouraged EPA to undertake more comprehensive analysis in future; concerned with "upstream" uncertainty
- NAS review of EPA benefits analysis framework (2002)
  - more comprehensive quantitative treatment of uncertainties in primary analysis, including use of expert elicitation (EE)
  - transparent presentation of results and associated uncertainties (both quantified and un-quantified)

Background (cont'd)

- Presented Uncertainty Plan to SAB Council – 2003.
- Revised approach in 2007 White Paper to reflect new developments:
  - Refinement of 812 Study scenarios;
  - Completion of PM Mortality Expert Elicitation Study;
  - New BenMAP capabilities for sensitivity analysis;
  - NCEE-sponsored uncertainty analysis study by RFF; and
  - Development of EPA Response Surface Modeling (RSM) meta-models.

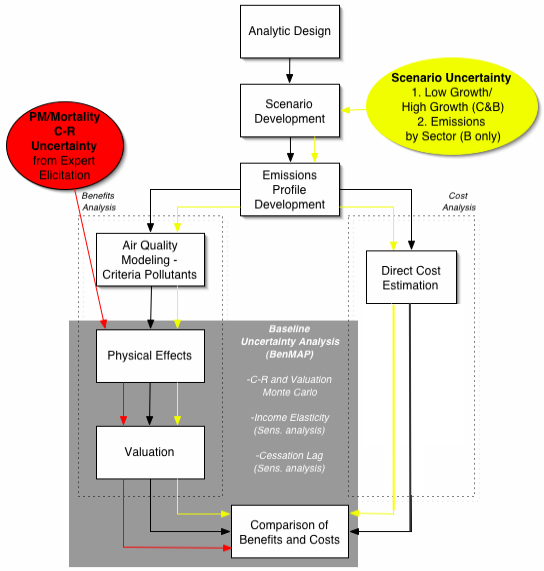
Objectives

- Identify reasonable incremental advances in uncertainty analysis suitable for application within a complex national-scale study;
- Conduct sensitivity analyses that provide policy-relevant insights concerning impacts of alternative assumptions on benefit and cost estimates for the CAA;
- Where appropriate, incorporate EPA's latest tools and data for uncertainty analysis (e.g. PM mortality expert elicitation, RSM); and
- Enhance presentation of results and uncertainty through the use of graphical tools to complement tabular summaries.

Overview of Uncertainty Plan

- Scenario Analysis (Online)
- Expanded Uncertainty Analysis of Benefits (Online)
- Offline Uncertainty Analyses
- Enhanced Presentation Tools

Proposed "Online" Quantitative Uncertainty Analyses



Proposed "Offline" Uncertainty Analyses

Issue	Recommended approach	Analytical Elements affected	Output
Emissions/Air Quality Parameter Uncertainty	Identification of key factors coupled with scalable sensitivity analysis	Emissions and air quality modeling	Current state of knowledge concerning uncertainty assessment for large-scale air quality modeling applications. Limited quantitative information on impact on AQ outcomes.
Emissions Scenario uncertainty	Break-even analysis by sector using RSM and BenMAP, coupled with interviews of emissions modeling experts	Benefits side elements	Assessment of the likelihood of emissions scenarios (or errors in emissions estimation) resulting in negative net benefits for particular sectors.
Unquantified uncertainties	Comprehensive qualitative uncertainty analysis	All	Summary tables at the end of each chapter describing key uncertainties and the size and direction of their likely impact on results (if known).

Source: "Estimating Uncertainty in the Second 812 Prospective Analysis of the Benefits and Costs of the Clean Air Act,." Draft White Paper, February 16 2007.

Example Uncertainty Table

Uncertainties Associated With Emissions Modeling Identified in the First Prospective Analysis

Key Uncertainties Associated with Emissions Estimation Potential Source of Error	Direction of Potential Bias for Net Benefits Estimate	Likely Significance Relative to Key Uncertainties in Net Benefit Estimate*
Primary PM2.5 emissions estimates are based on unit emissions that may not accurately reflect composition and mobility of the particles. For example, the ratio of crustal to primary carbonaceous particulate material likely is high.	Underestimate. The effect of overestimating crustal emissions and underestimating carbonaceous when applied in later stages of the analysis, is to reduce the net impact of the CAAA on primary PM2.5 emissions by underestimating PM2.5 emissions reductions associated with mobile source tailpipe controls.	Potentially major. Mobile source primary carbonaceous particles are a significant contributor to public exposure to PM2.5. Overall, however, compared to secondary PM2.5 precursor emissions, changes in primary PM2.5 emissions have only a small impact on PM2.5 related benefits.
The Post-CAAA scenario includes implementation of a region-wide NOx emissions reduction strategy to control regional transport of ozone that may not reflect the NOx controls that are actually implemented in a regional ozone transport rule.	Unable to determine based on current information.	Probably minor. Overall, magnitude of estimated emissions reductions is comparable to that in expected future regional transport rule. In some areas of the 37 state region, emissions reductions are expected to be overestimated, bur in other areas, NOx inhibition of ozone leads to underestimates of ozone benefits (e.g., some eastern urban centers).

* The classification of each potential source of error reflects the best judgment of the section 812 Project Team. The Project Team assigns a classification of "potentially major" if a plausible alternative assumption or approach could influence the overall monetary benefit estimate by approximately five percent or more; if an alternative assumption or approach is likely to change the total benefit estimate by less than five percent, the Project Team assigns a classification of "probably minor."

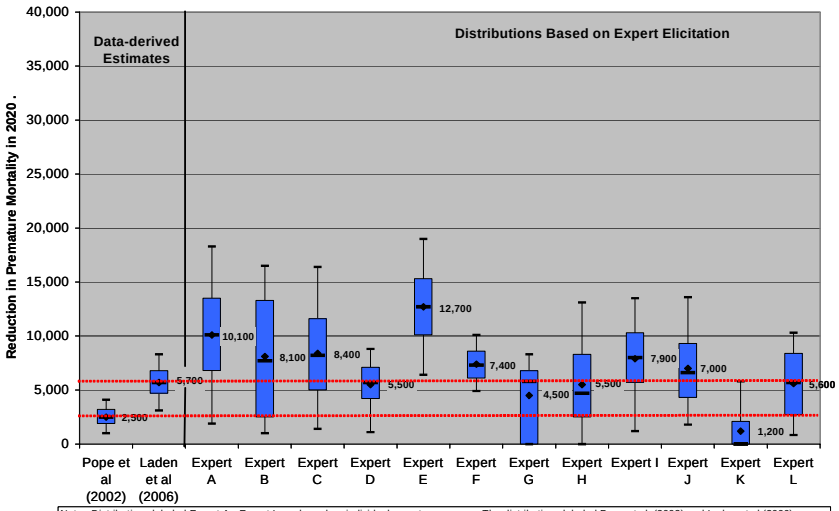
Scenario Analyses

- Address temporal prediction uncertainty
- Monte Carlo analysis impractical; better to analyze alternative sets of related future assumptions.
- Useful "when the relative weights of the different parameter states cannot be estimated through expert judgment or a reasonable averaging method," (RFF, 2006)
- Proposed Scenarios:
  - Economic/Population Growth
  - Emissions scenarios by sector
- No "High-Renewables" – unlikely to see significant shift by 2020.
- No Natural Gas Price scenarios – expect little impact on net benefits; see RFF (2006).

Expanded Benefits Uncertainty Analysis - Mortality

- Previous approach:
  - Primary estimate used Monte Carlo analysis with effect distribution based on reported relative risk (RR) and standard error from Pope et al. 2002.
  - Supplemental sensitivity analysis with alternative studies (e.g. Dockery et al., 1993).
- Proposal: Present both empirical-based and expert elicitation (EE) estimates of avoided mortality.
  - Empirical estimates calculated as in First Prospective (studies TBD).
  - EE-based results from 2006 EPA PM-mortality EE study (IEc, 2006).
    - Structured, in-depth interviews of 12 peer-nominated experts in epidemiology, toxicology, and medicine.
    - 12 probabilistic distributions of the impact of a 1 $\mu g/m^3$ decrease in annual average $PM_{2.5}$ in the U.S. on annual, adult mortality.
    - Comprehensive characterization including factors affecting parameter uncertainty (e.g. exposure misclassification) and model uncertainty (shape of the C-R function).
    - Peer reviewed.
    - Applied in 2006 PM NAAQS RIA.

PM-Mortality Expert Elicitation Results Applied in EPA's 2006 PM NAAQS RIA



Note: Distributions labeled Expert A - Expert L are based on individual expert responses. The distributions labeled Pope et al. (2002) and Laden et al (2006) are based on the means and standard errors of the C-R functions from the studies. The red dotted lines enclose a range bounded by the means of the two data-derived distributions.

Expanded Benefits Uncertainty Analysis – Mortality (cont'd)

- Differential Toxicity
  - Insufficient data to support sensitivity analysis.
  - Consider apportioning by species as in NAAQS RIA (Fig 5-16).
- Cessation lag
  - Previous approach
    - 5-year timeframe (25%, 25%, 17%, 17%, 17%)
    - Supported by smoking literature.
  - Current approach
    - 20-year timeframe (Year 1: 30%; Years 2-5: 50% (evenly spread); Years 6-20: 20% (evenly spread).
    - Reflects PM-specific analysis related to intervention studies. (SAB, 2004)
  - No definitive study of lag structure; propose sensitivity analysis, consistent with 2004 SAB advice.
  - Implement with BenMAP or dynamic population simulation model developed for OPAR.

Expanded Benefits Uncertainty Analysis - Valuation

- VSL options:
  - Apply default approach in EPA Guidelines
    - 26-study Weibull distribution, $6.1M mean (1999$).
    - Based on approach used in 812 analyses.
  - Apply current OAR approach
    - Normal distribution, $5.5M mean (1999$).
    - 5th %ile = $1M (25th %ile from Mrozek & Taylor).
    - 95th %ile = $10M (75th %ile from Viscusi & Aldy).
  - Develop new approach
    - Several possible variants:
      - Use Viscusi & Aldy only (as suggested in 2004 Council Advisory)
      - Use Kochi et al. only
      - Use Viscusi & Aldy and Kochi et al. meta-analyses in combination.

Expanded Benefits Uncertainty Analysis – Valuation (cont'd)

- Income elasticity
  - EPA proposed in May 2003 Analytical Plan to adjust unit values for health effects and residential visibility for income elasticity using 1999 literature review of values.
  - In response to SAB council advice, EPA updated lit review in 2004.
    - Recommends low, central, & high elasticity values for mild, chronic/severe, and mortality impacts.
  - Use central income elasticity from 2004 lit review, coupled with GDP/income and population growth projections from AEO 2005.
  - Perform sensitivity analysis using BenMAP.

Offline Analysis – RSM

- Reduced-form "meta-models" based on response-surface modeling (RSM) of a large set of index runs of full-scale model.
- Predicts AQM outputs from CMAQ (PM) or CAMx (O_3) using statistical relationships of inputs to outputs.
- Previously applied in support of MSAT and PM NAAQS rules.
- AQMS reviewed RSM plans; appeared supportive.
- More efficient and economical tool for analysis of impacts of uncertainties in emissions and other AQM inputs.
- Propose to couple with BenMAP to generate benefit estimates for offline analyses.

Offline Analysis – Emissions and AQM

- A phased approach to characterizing uncertainties in integrated air quality modeling system (IAQMS) (See Sonoma Technology memo – Attachment 1).
- Addresses emissions, meteorology, chemistry, and model configuration uncertainties.
- Proposed phases:
  - Phase 1:Literature Review and Workshop to identify key IAQMS uncertainties;
  - Phase 2:Offline modeling (RSM/BenMAP) to assess effect of uncertainties on IAQMS predictions;
  - Phase 3: Offline modeling (RSM/BenMAP) to assess effect of uncertainties on IAQMS *response* to emission changes; and
  - Phase 4: Final Synthesis.
- Useful information at end of each phase; scalable.
- Likelihood of a semi-quantitative, overall "bottom-up" estimate of IAQMS uncertainty unclear.

Offline Analysis – Model Uncertainty for EGU Emissions

- Concerns about validity and reliability of 2001 IPM validation run proposed for 812 study's 2000 results.
  - Spatial distribution of emissions do not match continuous emissions monitor (CEM) data.
- August 2006 – EPA presents to AQMS alternative approach based on counterfactual for EGU SO_2 emissions (Ellerman method, see Attachment #3).
- AQMS agreed suitable for sensitivity analysis.
- Propose sensitivity analysis using CEM data for 2000/2001 with-CAAA case and Ellerman-method for without-CAAA case for EGU SO_2 emissions.

Offline Analysis – Break Even Analysis

- Objective: Assess how large uncertainty in emissions for each sector would have to be for B-C < 0.
- Steps:
  - Identify possible alternative scenarios
  - Reduced-form analyses with RSM/BenMAP
  - Identify scenarios where p(B-C <0) > 50%
  - Consult with emissions experts to characterize at least qualitatively the likelihood of scenarios identified in Step 3.
- Should provide some policy relevant insights into robustness of net benefit results for particular sectors, if downstream uncertainties also included in BenMAP runs.
- Results conditional on cost estimates being unbiased.

Presentation of Uncertainty

- Recommend additional use of graphical tools to complement tabular summaries.
- Qualitative: Support detailed summary tables as in 1st Prospective – source of error, likely direction of potential bias, likely significance.
- Quantitative:
  - Avoid appearance of unwarranted certainty (Exh. 5 in WP)
  - Graphical tools for comparing alternative scenarios
    - Box and Whiskers plots
    - PDFs
    - CDFs
    - Tornado diagrams

Next Steps

- Review Council feedback on data and methodological choices (Charge questions 3a, 3b).
- Consultation with SAB Subcommittees in Spring 2007.
- Finalize plan late spring 2007 in response to Council advice and any potential input from Subcommittees.
- Begin implementing uncertainty analysis late spring/early summer 2007.

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617.354.0074