



Retrospective Study of the Costs of EPA Regulations: An Interim Report of Five Case Studies

National Center for Environmental Economics

**Presentation to the Science Advisory Board's
Environmental Economics Advisory Committee**

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Outline



- Introduction
- Previous Literature
- Why are Ex Ante Cost Estimates Inaccurate?
- Methodology
- Preliminary Results of 5 Case Studies
 - Cluster Rule and MACT II Rule
 - Critical Use Exemption: Methyl Bromide
 - Arsenic Rule
 - Locomotive Emission Standards



- Background:
 - Long standing interest in retrospective analyses.
 - The quality/bias of our ex ante analyses?
 - Unintended consequences (good and bad)
 - The role of variables unaccounted for in ex ante analyses (e.g., technology innovation)?
 - Regulatory Look Back

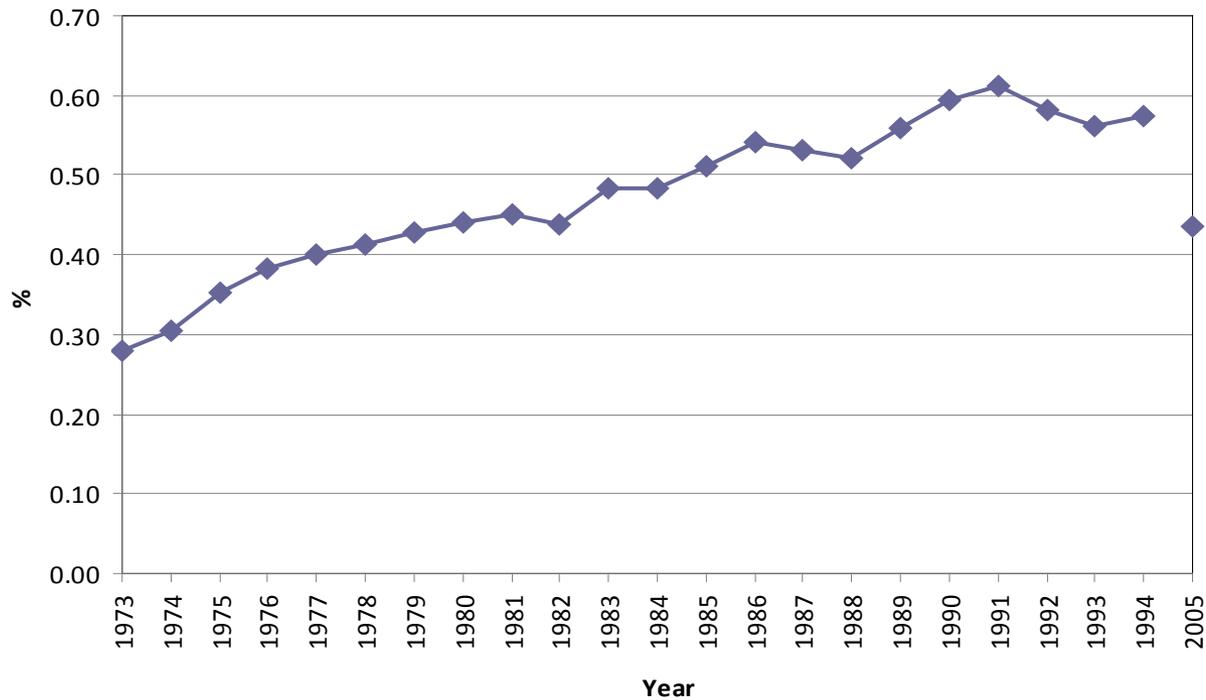
This study is among the list of EPA actions included in the regulatory review plan required by President Obama's Executive Order 13563 on “Improving Regulation and Regulatory Review.”

Pollution Abatement Costs



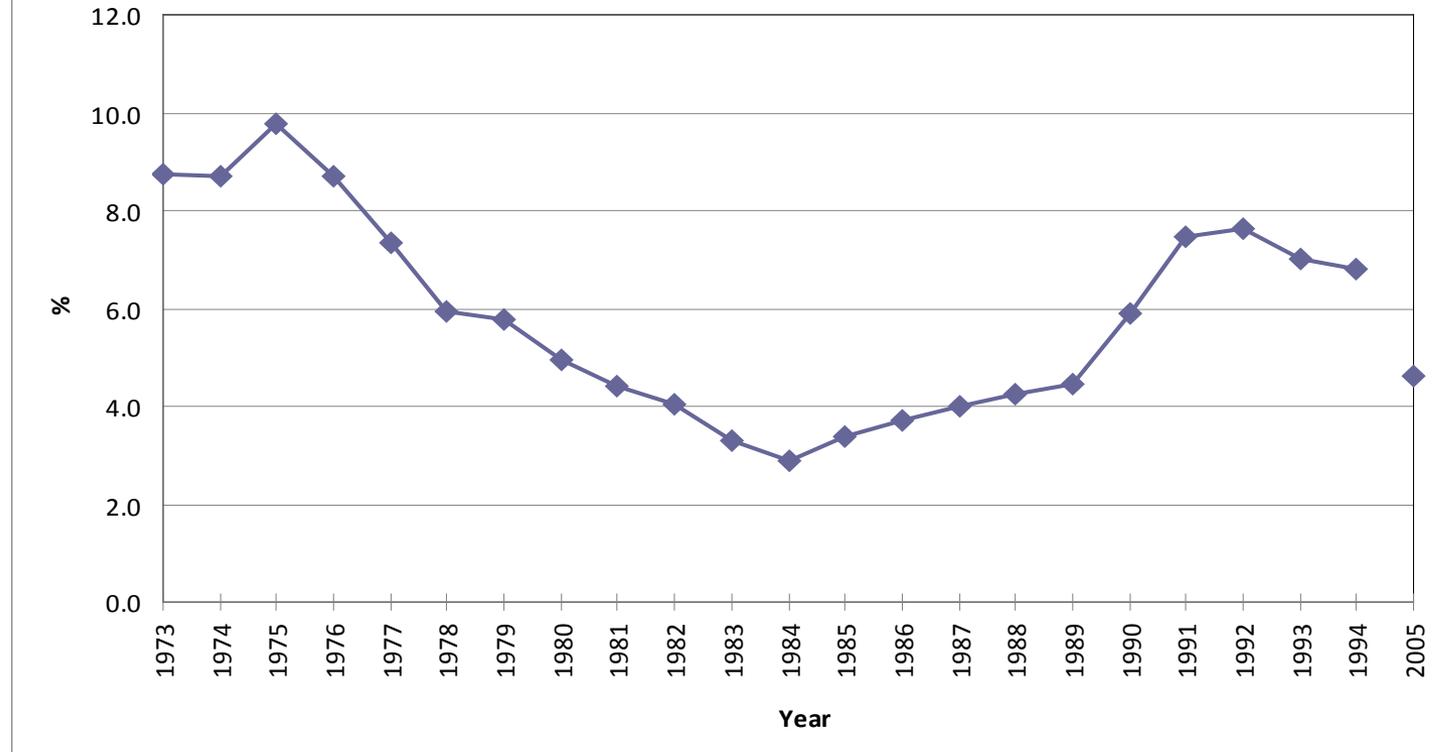
- Since the early 1970's the EPA has promulgated more and more stringent environmental regulations resulting in much cleaner air, water and land
- Even though regulatory stringency has been increasing over time on the manufacturing sector
 - Pollution abatement operating costs are still a very small percent of total revenues
 - Pollution abatement capital expenditures are a small percent of total capital expenditures

Pollution Abatement Operating Costs (PAOC) as a Percent of Total Revenues over time

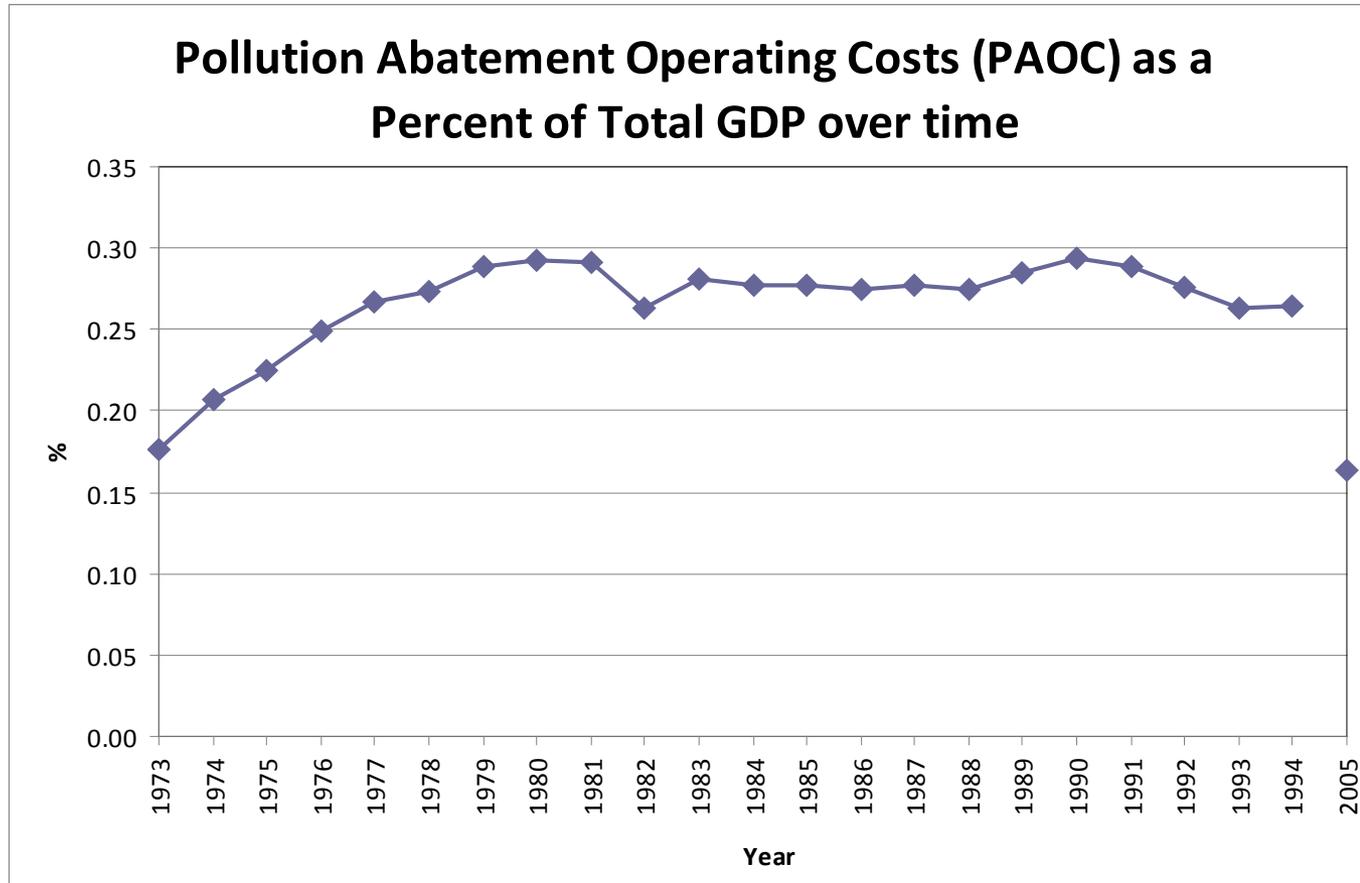


Sources: U.S Census Bureau - Pollution Abatement Costs and Expenditures Survey and Annual Survey of Manufactures

Pollution Abatement Capital Expenditures (PACI) as a Percent of Total New Capital Expenditures over time



Sources: U.S. Census Bureau - Pollution Abatement Costs and Expenditures Survey and Annual Survey of Manufactures



Sources: Economic Report of the President, Executive Office of the President and Pollution Abatement Costs and Expenditures Survey, U.S. Census Bureau

Introduction



- Available studies (of which there are few) have shown that ex ante cost estimates often differ from ex-post cost estimates of regulations
- Despite these findings, EPA has not systematically examined ex ante vs. ex post costs of its regulations or reasons for any difference
- **Objective of our study:**
 - The goal is to determine whether ex-ante and ex-post cost estimates vary systematically by a substantial degree (+/- 25 percent?), and if so, determine the sources of these differences to improve ways of estimating compliance costs.

Overarching concerns



- Tradeoff between scope and detail.
 - Could not duplicate the rigor of the RIA with ex post data and complete sufficient case studies for insights.
 - Instead, we employ a case study approach
 - look at the drivers of costs, available data, trends etc.
 - use a “weight of evidence” determination about unit costs and total costs.
- Were unsure about which data gathering approaches would work
- Worried about “cherry picking”

Introduction



- Challenges encountered thus far:
 - LACK OF DATA on compliance strategies used by affected facilities and their associated costs
 - Lack of help from associations; limited number of industry experts; securing participation from identified experts required considerable effort
 - Difficulty in evaluating a highly heterogeneous industry with a limited set of information
 - Limited ability to construct a reasonable counterfactual
 - Difficulty in disentangling costs of compliance from other factors
 - Difficulty in establishing appropriate baseline

Previous literature



- Focused on *surveys of studies*, not original case studies of *ex ante* vs. *ex post* estimates.
- 10 studies surveyed
 - Domestic: Putnam, Hayes, & Bartlett (1980); OTA (1990); Hodges (1997; also Goodstein & Hodges, 1997); Harrington, Morgenstern, and Nelson (2000); Anderson & Sherwood (2002); OMB (2005); Dale, *et al.* (2009)
 - International: Bailey, *et al.* (2002), MacLeod, *et al.* (2006); Oosterhuis, *et al.* (2006; incorporating earlier studies): + a couple of examples in Harrington, *et al.*

What the literature shows



- Costs far more often over- than underestimated.
- Average ratio of *ex ante/ex post* estimates > > 1.
- Definitions of “cost” are not consistent across, or sometimes even within, studies.
- It’s hard to assemble a large, consistent data set.
- The problem with existing estimates may not be so much that they’re biased as that they’re all over the place, from
 - 5 times too low to
 - 11 times too high.

Why are cost estimates inaccurate?



- **Majority view:**

Regulatory analysis is notorious for failing to take into adequate account the technological innovations that ultimately make many regulations cheaper to implement than regulators anticipate.

Heinzerling (2002)

- Numerous examples, most spectacular is CAAA of 1990

Other possible explanations



- Timing
 - We base estimates on first draft of rule, actual rule may be considerably weakened.
 - We do our analyses years before rules take effect.
- Do regulated entities really comply 100%?
- If we're going to implement the rule anyway, why bother to parse costs carefully?
- We get information from industry; they may overestimate costs because...
 - They hope less onerous regulations will result; and/or
 - There is little incentive for them to search for the least-cost approach.
- Selection bias:
 - Advocates may choose examples that support their views.
 - Economists like to demonstrate superiority of MBIs.

Some countervailing considerations



- “Raising rivals’ costs”: in heterogeneous industries, there may a constituency for stricter regulations.
- “Regulatory aggrandizement”: overly zealous regulators might low-ball costs to expand reach.
- We may not fully consider administrative costs, spillovers, dynamic effects.

Summary of the evidence



- Most estimates are too high;
- The ratio of *ex ante* to *ex post* estimates is $\gg 1$.

But...

- Neither fact necessarily implies *ex ante* estimates are biased.
- Skewed distributions \Rightarrow mean \neq median
- Jensen's inequality \Rightarrow mean of quotient $>$ quotient of mean.
- Simple regression test on very limited data found we cannot reject hypothesis that *ex ante* estimates are unbiased predictors of *ex post*.

Selection of Rules:

- RAPIDS search of “economically significant” rules promulgated since 1995 generated a list of 111 rules
- We discarded duplicate entries and rules:
 - not yet implemented
 - remanded by the courts
 - consisting of minor amendments to existing rules
 - noted to be “Other significant action” but not meeting \$100 million benefit-cost criteria for E.O.12866, or
 - difficult to analyze (e.g. multi-sector nature of NAAQS)
- Resulting inventory consists of 42 rules promulgated 1995-2005

Selection of Rules:

- To date, we have selected 10 rules for RCS
- Phase I rules
 - serve as pilot case studies to help test various ex-post cost estimation methodologies
 - chosen to cover various media, source categories, types of regulations (e.g., performance std vs. technology based)
 - four taken from the master list; fifth is a critical use exemption nomination of a fumigant suggested by OPP
- Phase II rules
 - chosen from the master list using stratified random sampling
 - 3 OAR rules, 2 OW

Four methodologies for collecting ex-post cost information

1. Rely solely on publicly available data sources
 2. Consult industry experts on compliance strategy and costs
 3. Conduct plant visits by economist and environmental engineer
 4. Explore possibility of administering a comprehensive industry survey
- Methods #1 and #2 have been used in the 5 case studies performed to date.

The 1998 Integrated NESHAP and Effluent Guidelines for Pulp and Paper

and

The 2001 NESHAP for Chemical Recovery Combustion Sources at Kraft, Soda, Sulfite and Stand-Alone Semichemical Pulp Mills

Cluster Rule and MACT II Rule



- **Integrated NESHAP and Effluent Guidelines for Pulp and Paper (1998)**
 - Together, the combined 1998 standards and guidelines became known as the “**Cluster Rule**” because they consisted of integrated air and water rulemakings.
 - Compliance dates:
 - Air Provisions: 2001 (most provisions)
 - Water Provisions: Upon renewal of NPDES permit
- **NESHAP: Chemical Recovery Combustion Sources at Kraft, Soda, Sulfite and Stand-Alone Semichemical Pulp Mills (2001) - MACT II**
 - Compliance date: 2004

Cluster Rule



- **Air pollutants** - EPA set MACT standards (referred to as MACT I & III) that required mills to capture and treat toxic air pollutant emissions that occurred during the pulping and bleaching stages of the manufacturing process.
 - The HAPs covered by the Cluster Rule included compounds such as methanol, chlorinated compounds, formaldehyde, benzene, and xylene.
- **Water pollutants** – EPA set effluent limits for toxic pollutants in the wastewater discharged during the bleaching process and in the final discharge from the mills.
 - Best available technology (BAT) effluent limits and pretreatment standards for existing sources (PSES), were based on substituting chlorine dioxide for chlorine in the bleaching process (i.e., using elemental chlorine-free bleaching [ECF]) or using totally chlorine-free (TCF) bleaching.

MACT II



- The MACT II standards covered HAP metals and gaseous organic HAPs during chemical recovery stage
 - PM was used as a proxy for HAP metals
 - Methanol and total hydrocarbons were used as proxies for gaseous organic HAPs.
- For existing kraft and soda mills, a “PM bubble compliance alternative” allowed mills to set PM limits for each emission point, as long as the aggregate of these PM limits was equal to the aggregated promulgated PM limits of the individual emission points.



- **Cluster Rule (1998)**

- For this case study, we rely on aggregate publicly available data from the National Council for Air and Stream Improvement, Inc. (NCASI) which produced an annual survey of capital expenditures borne by pulp and paper firms from 1970 to 2001.
- We also use data found in the SEC 10-K form which provides some firm-level data for both ex ante and ex post costs of Cluster Rule compliance.

- **MACT II (2001)**

- For this case study, we rely on information provided by Research Triangle Institute through Abt Associates.
- RTI estimated the ex post costs using information on the actual (ex post) compliance methods selected by individual mills and estimated compliance costs from the engineering firm BE&K that were matched to the selected compliance methods.

Cluster Rule – Baseline Issues



- The NCASI survey does not provide estimates of pollution abatement capital expenditures specifically associated with the Cluster Rule.
- In order to estimate the incremental capital costs of the Cluster Rule, it is necessary to compare the capital expenditures during the compliance period against a baseline (counterfactual) level of pollution abatement capital expenditures.
- The **baseline** represents the best assessment of world absent the proposed regulation or policy action.
- Baseline specification can have a major influence on the outcome of an economic analysis.
 - A careful and correct baseline specification has a strong influence on the accuracy of the incremental benefit and cost estimates.

Cluster Rule – Baseline Issues



Challenges in constructing an appropriate baseline:

- Intention to regulate was signaled before promulgation in 1998. In 1988 consent decree with EDF and NWF, EPA agreed
 - to propose effluent guideline limitations (EGLs) on dioxins from pulp and paper mills by October, 1993
 - to develop rules to regulate discharges of dioxins within 18 months of the date of the proposed EGLs
- Some evidence that the pulp and paper industry started to *voluntarily* reduce discharges of dioxin in the late 80's and early 90's due to public pressure
 - A 1990 New York Times article noted that Red Caveny, then president of the trade organization American Paper Industry, stated that “mills making paper for milk cartons had voluntarily lowered the levels of dioxin in their product by 96 percent in the last two years.”
- This makes it particularly challenging to select an appropriate baseline in this case.

Cluster Rule – Baseline Issues



- In our analysis of the Cluster Rule we gave considerable thought as to how to define our pre-Cluster Rule baseline. We settled on a preferred baseline of the average air and water capital expenditures from 1995-1997
 - For sensitivity analysis, we used two additional baselines: air and water capital expenditures in either 1996 or 1997
- The new NCASI study (received last week from AF&PA), which focuses on the BAT/PSES provisions of the Cluster Rule, used a pre-Cluster Rule baseline of average water capital expenditures from 1981-1986
- We may be able to further refine our baseline assumptions for this case study in order to better determine if/when mills began abatement investment in anticipation of the rule (versus public pressure or other factors).
 - For a separate project at the Census Bureau on the Cluster Rule we are using the Pollution Abatement Costs and Expenditures micro data and/or Census of Manufacturers data micro data on investment to help identify when mills complied with both the air and water provisions of the Cluster Rule.
- We would appreciate any advice you could provide on how to construct a scientifically defensible baseline for our analysis.

Cluster Rule – Preliminary Conclusions



Our **preliminary** findings *suggest* that EPA over estimated the costs of the Cluster Rule.

- We find that EPA over-estimated the capital cost of the Cluster Rule by 30% to 100% depending on the choice of baseline year from which we derived the incremental cost.
- Given the lack of detail in our data, we are currently unable to speculate as to why EPA overestimated these capital costs.

MACT II – Preliminary Conclusions



Our **preliminary** findings *suggest* that EPA overestimated Total Capital Investment in response to MACT II by roughly 25% and overestimated Total Annualized Costs by nearly 5 times.

- We believe the main reason for the lower ex-post costs of MACT II is that facilities took advantage of the "bubble compliance alternative" strategy
 - This strategy allowed for much more efficient methods to abate the same level of PM emissions
 - Bubble compliance strategy was not reflected in EPA's ex-ante cost estimates.

Challenges and Limitations



Cluster Rule

- We only had access to industry level data from NCASI, so our results are at least somewhat sensitive to how we construct the baseline

MACT II

- The only industry compliance expert that could provide us with ex post cost information also supported the ex ante cost analysis for the rule and we could not independently verify the accuracy of the data
- The ex post cost data was estimated by the contractor using a combination of ex ante engineering cost data, developed by BE&K, based on experience of similar projects in the pulp and paper industry and the actual (ex post) compliance methods chosen by the mills.



Retrospective Analysis of Methyl Bromide (MBr) Critical Use Exemptions: California Open-Field Strawberries

MBr Critical Use Exemption Background



- Widely used as a fumigant to effectively control pests in a variety of agricultural sectors.
- But depletes stratospheric ozone layer and was phased out from 1993 to 2005 under the CAA and Montreal Protocol.
 - One reason for the long phase out was to allow for the development of competitive substitutes
- After 2005, US agricultural users of MBr are allowed to apply annually for a critical use exemption (CUE) to the ban on its use.
- A CUE can be granted if
 - discontinued use of MBr would cause significant market disruption, or
 - there are no technically and economically feasible substitutes available.
- Early exemptions were largely granted on technical grounds, but economics has become more important recently

Why Strawberries in California?



- We focus on critical use exemptions for the 2006 – 2010 seasons for open field strawberries in California
 - Wanted a cost analysis for a pesticide or toxic; found it challenging to identify a case study
 - Prior to phasing out methyl bromide, growers in FL and CA accounted for >75% of its use on pre-plant soils.
 - The best disaggregated data on fumigant use for fruit and vegetable crops are from California.
 - We focus on assessing the costs of critical use exemptions when the amount granted is less than what was originally requested (candidates: strawberries, tomatoes, peppers).
 - Open field strawberries are a good candidate due to better quality and relatively reliable data.

Ex-Post Cost Assessment



- Rely on publically available data for this case study
- Chose 2006-2010 seasons (evaluated by EPA in 2004-2008) because some ex-post data are available
- Largely limited to an assessment of unit (per acre) operating costs because it is the only information evaluated by EPA ex-ante in the CUEs.
- Speak to the role of regulatory constraints, but do not evaluate extent to which EPA accurately characterized them.

EPA Ex-Ante Analysis



- Per United Nations guidance, each year EPA conducts financial analyses of the effect of discontinued MBr use on a typical farmer for a crop and region seeking exemption
- No aggregate estimate of net costs is provided by EPA as part of the CUE nomination package
 - For a typical farmer, calculate revenues (market price * yield) and operating costs per hectare for MBr and several alternatives to assess economic feasibility
- Because EPA is assessing burden associated with switching to a MBr alternative, the baseline against which they are assessed is the continued use of MBr.

Review of the Literature



- A search of the literature and emails to key researchers found only one published ex-post analysis.
- Mayfield and Norman (forthcoming) examine if CA strawberry farmers have been negatively impacted by the phase-out
 - Little support for this hypothesis, in part due to generous exemptions.
 - No formal counterfactual is evaluated, but point to rising yields, acreage, exports, revenues and market share as evidence that industry has not faced substantial negative impacts.
- The ex-ante literature disagrees regarding the likely impact of banning MBr on U.S. farmers and the economy.
 - Initial studies tend to predict larger impacts than later studies in part because they often evaluate an immediate and complete ban and assume no technological innovation over time.
 - Another key difference stems from assumptions regarding Mexico's ability to rapidly increase strawberry exports to the U.S. market.

Main Data Sources for Ex-Post Assessment



- Critical Use Nomination packages for “future” years
- USDA Fruit and Vegetable Statistics – overall statistics on prices, acreage and yield of strawberries in California
- California Pesticides Information Portal – what fumigant is applied by county and year, including amount and acreage
- UC-David Cost Studies – crop budgets with typical unit cost of producing strawberries
- Peer-reviewed literature and 2006 UN-funded meta analysis on yield losses of MBr alternatives

PRELIMINARY Results



- California farmers used about the amount of methyl bromide expected to grow strawberries during this period.
- Only the chemicals analyzed by EPA – 1,3-dichloropropene (1,3-D) + chloropicrin (PIC), PIC + MS, and MS alone - were used as substitutes
 - CA strawberry farmers have generally not recombined them in novel ways
- As anticipated, California regulatory restrictions limited the use of several economically competitive alternatives.
 - Township caps on 1,3-D are binding for many areas that grow strawberries
 - Application rates for volatile organic compounds (PIC and MS) are restricted
 - Buffer zone requirements further restrict the use of various alternatives
 - Iodomethane was only recently registered for use in California and has proven controversial.
- Ex-ante operating cost projections appear to be consistent with available ex-post data.

PRELIMINARY Results



- For the initial set of years, EPA was relatively accurate in its assessment of the rate at which MBr would be applied.
- The 2012 nomination package notes two factors that have slowed the transition to MBr alternatives :
 - California restrictions on chloropicrin mean that the lowest formulation likely allowed is 57 parts MBr to 43 parts chloropicrin.
 - Unanticipated complications after switching away from methyl bromide, such as new diseases, has slowed the transition to MBr alternatives, in particular 1,3-D+PIC applied via drip irrigation.
- A recent UN assessment points to a third possible reason:
 - Low permeability films allow for significantly lower MBr application rates without loss of effectiveness or discernible impact on yields.
 - While required in EU, CA does not allow low permeability films to be used with MBr due to concerns about worker exposure.

PRELIMINARY Results



- The estimate of gross revenues is predicated on ability to anticipate future strawberry prices and changes in yields.
 - EPA appears to have been reasonably accurate in its forecast of future strawberry prices
 - Difference is in assumed yield loss in later seasons.
 - Literature indicates that a number of the MBr alternatives analyzed may have become available more quickly and resulted in lower yield loss than initially anticipated.
 - Farmers appear to have been able to substitute away from MBr without large negative impacts on production in prime strawberry growing areas.

Challenges and Limitations



- Only have information on operating costs from crop budgets designed to reflect a typical farmer.
- No information on prices of specific fumigant formulations.
- Data on yield losses associated with methyl bromide alternatives are based on field trials.
- While there is detailed annual data on what fumigants farmers used, no information on other management practices (e.g., type of tarp used).
- Analytically challenging to evaluate counterfactual: what farmers would have done if they had not received MBr exemptions for the 2006-2010 seasons.



2001 National Primary Drinking Water Regulation for Arsenic

The Arsenic Rule: Background



- National Primary Drinking Water Regulation for Arsenic was published on January 22, 2001
- Lowered the Maximum Contaminant Limit (MCL) for arsenic in drinking water from 50 micrograms/liter ($\mu\text{g}/\text{L}$) to 10 $\mu\text{g}/\text{L}$.
- EPA estimated that about 3,000 (out of 54,000) Community Water Systems and 1,100 (out of 20,000) Non-Transient Non-Community Water Systems would initially not meet the 10 $\mu\text{g}/\text{L}$ standard and would need to treat their water.
- Of those systems affected, 97 percent serve 10,000 people or fewer.

Treatment Technologies



- EPA identified six centralized treatment technologies as BATs:
 - Modified Lime Softening
 - Modified Coagulation/Filtration
 - Ion Exchange
 - Coagulation Assisted Microfiltration
 - Oxidation Filtration (Greensand)
 - Activated Alumina
- EPA identified POU devices for small systems:
 - POU Reverse Osmosis
 - POU Activated Alumina
- Developed unit cost curves for each technology

Economic Analysis (Ex Ante Costs)



- Economic Analysis estimated compliance costs for
 - small (less than 1,000,000 people)
 - large CWS (more than 1,000,000 people)
 - NTNCWS (e.g., schools, hospitals)
- Safewater XL model
 - Select system, determine sites (entry points) that will exceed MCL, assign treatment, estimate how much of the flow will need to be treated
- Using average and design flow for the system and the cost equations and the resulting cost curves, capital and O&M costs were calculated for each treatment technology.

Our Limited Sources of Information



- Anecdotal information from selected states and independent associations on frequency of use of various mitigation strategies.
 - AMWA and ACWA
 - Maine, Michigan, Nevada and Washington
- ORD Demonstration Projects
- Industry Compliance Engineering Firms
 - Wright Pierce
 - Malcom Pirnie

The Arsenic Rule: States



- **Maine**
 - 82 systems had to treat, with about 95% of those serving less than 1,000 people.
 - Majority of systems (67%) adopted some form of adsorptive media
- **Michigan**
 - 116 systems had to treat; roughly 83% of those systems served less than 1000 people
 - Over half adopted a technology including iron-based adsorptive media
 - Disposal of backwash was a problem
- **Nevada**
 - 105 out of 326 systems had to treat; currently 43 have not achieved compliance yet
 - Adsorptive media was commonly used
- **Washington**
 - Although adsorptive media was used (25%), greensand filtration was the most commonly used technology (33%); 17% used non-treatment options while 14% used blending

The Arsenic Rule: ORD Data



- At this time, we only use the ex post cost data from the ORD Demonstration Projects
 - Will include the data from the two engineering firms once we have verified the costs are specific to arsenic mitigation and do not include costs associated with other unrelated water treatment or improvement activities.
- 50 ORD Demonstration Projects (26 States)
 - 42 CWS, 8 NTNCWS
- Iron-based adsorptive media has emerged as one of the preferred treatment technologies.
 - Used by 28 of the 50 ORD projects
- Other technologies represented:
 - Ion exchange
 - Greensand Filtration
 - Coagulation/Filtration
 - Reverse Osmosis
 - POU technology
- Capital cost expenditures reported for all projects, O&M expenditures reported for most projects.

The Arsenic Rule: Our Evaluation



- Our analysis is a demonstration of how we could compare ex ante and ex post cost if we had representative data.
- Using the ORD data we compare realized, ex post costs with predicted (ex ante) costs using cost curves for BATs recommended for small systems.
 - Ion Exchange
 - Activated Alumina
 - Greensand Filtration
- For two BATs used in ORD projects: Compare realized, ex post costs with predicted capital costs estimated using EPA's technology cost curves.
 - Ion exchange
 - Greensand Filtration

The Arsenic Rule: Our Findings



We cannot draw any conclusions with our limited data.

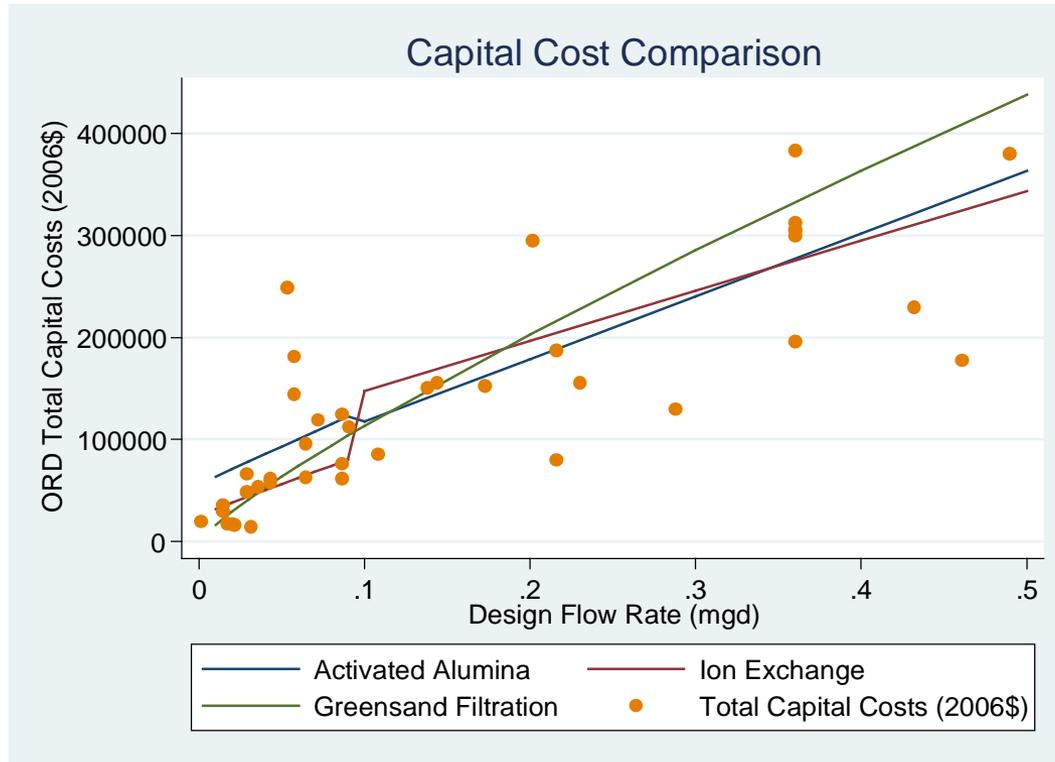
Our comparison of realized and predicted costs are mixed and not generalizable.

ORD Demonstration Projects:

- Ex post capital costs tend to be higher than ex ante costs for smaller systems
- However, as the size of the system increases, ex post capital costs tend to be lower than ex ante
- BATs: For ion exchange and greensand filtration, ex post costs were mostly higher than EPA estimates.

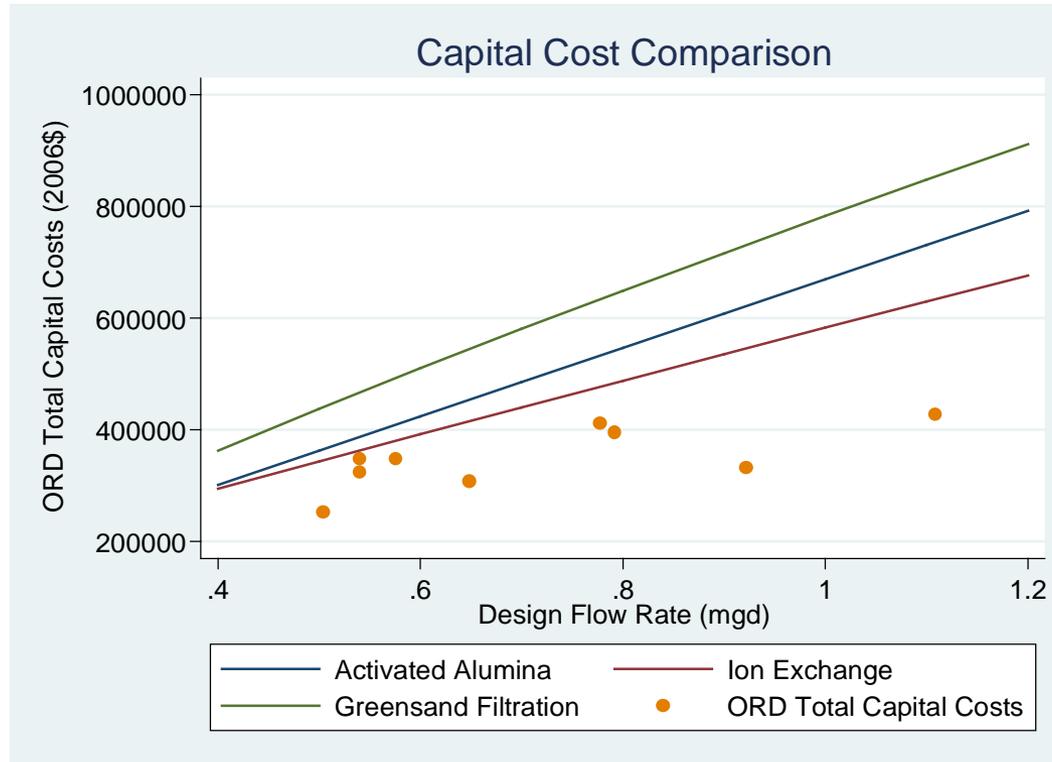
EPA Cost Curves vs. ORD CWS Projects

Design Flow Rate (0-0.5 mgd)



EPA Cost Curves vs. ORD CWS Projects

Design Flow Rate (> 0.5 mgd)



Analytic Challenges



- Cannot draw conclusions due to lack of data. Results are not generalizable across affected systems.
- Heterogeneity among affected water systems.
- Comprehensive cost information for the treatment technologies installed by all systems affected by the rule is not available.
- Comprehensive information on the other mitigation strategies pursued by water systems is not available.
- Most of our data is from systems that used some form of iron-based adsorptive media.
- Data may also be biased:
 - Not representative of all systems/technologies
 - Demonstration projects were chosen to demonstrate a particular technology



1998 Locomotive Emission Standards

Locomotive Rule



- Promulgated in April 1998
- Subjected locomotive manufacturers and railroads to emission standards, test procedures, and a full compliance program
- Applied to all locomotives manufactured in 2000 and later, and any remanufactured locomotive originally built after 1973
- Established three separate sets (Tiers) of emission standards (HC, CO, NO_x, PM, smoke), with applicability dependent on the locomotive's date of manufacture:
 - Tier 0: locomotives originally manufactured 1973-2001
 - Tier 1: locomotives originally manufactured 2002-2004
 - Tier 2: locomotives originally manufactured in 2005 or later.

EPA Ex Ante Analysis



- EPA developed model categories for each tier to represent different locomotive model types.
- Incremental per locomotive compliance costs (by model types) includes:
 - Initial compliance costs – fixed (research and development, engineering, certification, and testing costs) and variable (hardware, assembly cost per control technology), plus 20% manufacturer markup for overhead and profit
 - Operating costs - maintenance (costs associated with keeping locomotives in compliance with the standards through subsequent remanufactures) and fuel (cost of any fuel economy penalties associated with compliance)
- Total costs = Incremental per locomotive compliance costs x estimated #locomotives subject to the rule

Ex Post Cost Assessment



- For this case study, we rely primarily on information provided by one engineer from Engine, Fuel, and Emissions Engineering, Incorporated (EF&EE), journal articles (primarily authored by engineers from locomotive manufacturing firms), augmented by publicly available data where possible (e.g., American Association of Railroads)
- We limit our assessment to the compliance costs incurred over roughly the first decade of the program (2000-2009) because the universe of locomotives that were subject to the 1998 rule is limited to locomotives originally built or remanufactured between 2000 and 2009, after which revised standards (promulgated in 2008) began taking effect.

Methodological Challenges



- Lack of data, esp. on the actual costs of individual control technologies, fuel consumption and fuel economy of new and remanufactured locomotives
- Lack of help from associations; only 1 industry expert agreed to provide information (EF&EE)
- EF&EE helped develop EPA's ex ante analysis; limited to no documentation available for some EF&EE statements
- Limited ability to construct a counterfactual , esp. with respect to fuel economy
- Unable to address all parts of EPA's ex ante analysis – e.g., manufacturer markup on initial compliance cost, use of ABT

Preliminary Findings



- A number of ex-ante assumptions proved to be fairly accurate
 - locomotive model types
 - the types of compliance technologies
 - fixed costs and assembly costs for newly manufactured locomotives
 - hardware costs of each emission control technology, and
 - annual maintenance costs per locomotive.
- In other areas, ex-ante and ex-post estimates differed:
 - E.g., fuel price, number of suppliers, number of remanufactured engine families certified, usage rates for some technologies, number of locomotives subject to the rule

Aside on Locomotive Types



- 3 Classes of Railroads: Class I, II, III
 - Class I are largest – carry most interstate freight and passengers (>95% of all locomotive diesel consumption), buy almost all the new locomotives
- 2 types of operations in each Class: line-haul (travel between distant locations) and switch (primarily move railcars within a railway yard)
 - Line-haul locomotives account for over 92% of all Class I fuel consumption
 - Switch locomotives are older, rarely remanufactured
- We provide some assessment of the switch market but focus primarily on Class I line-hauls

Preliminary Findings (cont'd)



- **Line-haul: Per locomotive compliance cost likely higher than anticipated**
 - larger number of remanufacturing systems certified and larger number of suppliers increased fixed cost for remanufactured locomotives.
 - increased usage rates for some technologies caused variable costs for remanufactured locomotives to be higher than ex ante estimates.
 - operating costs per locomotive (new or remanufactured) may have been higher because actual fuel prices were much higher than anticipated.
 - the impact of the higher fuel price may have been partially offset by lower fuel consumption and/or lower fuel penalties, but the extent of this is not known.
 - compared to the counterfactual case in which the latest technical advances to optimize fuel consumption could have been used without regard to emissions, it is possible that the fuel economy penalties were higher than EPA's assumptions.

Preliminary Findings (cont'd)



- **Line-haul: Ex-post assessment of total cost is inconclusive.**
 - Over 2000-2009, the number of newly built line-haul locomotives was higher but the number of remanufactured line-haul locomotives was lower than EPA's estimate
 - It is difficult to tease out the extent to which this was driven by an industry reaction to the 1998 rule (or the 2008 rule) or by external factors
 - It is possible that the lower costs due to far fewer remanufactures taking place than anticipated may have outweighed the higher compliance costs from new line-hauls
- **Switch locomotives: Total costs were likely lower than anticipated,** but this has not had a major impact because switchers comprise a relatively minor part of the overall locomotive market

Summary of Findings



Component of Cost Estimate	Source of Ex Post Information	Assessment (compared to ex ante)
Locomotive Models Types	EF&EE	Reasonable
Technology Types	EF&EE + journal articles	Reasonable
Technology Usage Rates	EF&EE + journal articles	Higher than anticipated for some technologies on some model types
Fixed Cost	EF&EE + EPA certification data	New- Reasonable Remanufactured – Higher than projected
Per Locomotive Variable Cost - Hardware	EF&EE + journal articles	Line Haul – Higher than projected Switch – Inconclusive
Per Locomotive Variable Cost - Assembly	EF&EE	New- Reasonable Remanufactured - Higher than projected
Fuel Price	AAR	Higher than projected
Annual Fuel Consumption	EF&EE for line haul genset websites for switch	Line Haul – Reasonable Switch – Lower
Fuel Economy Penalty	EF&EE+ journal articles, AAR, FRA , manufacturer promotional materials	Line Haul – Likely higher Remanufactured Switch –Likely higher
Maintenance Costs	EF&EE	Reasonable
Number of Affected Units	AAR for all Class I EF&EE for switch	New – Higher Remanufactured - Lower Switch – Lower
TOTAL COSTS	Line Haul – INCONCLUSIVE Switch – LIKELY LOWER (very few remanufactured and new units adopted alternate technology, but with some support from air quality grants)	