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## Retrospective cost analyses of EPA regulations: a case study approach

**Abstract:** EPA has conducted several *ex post* assessments of regulatory compliance costs, with the ultimate goal of identifying ways to improve *ex ante* cost estimation. The work to date has culminated in four case studies that examine five regulations using a common conceptual framework. The standardized framework provides a systematic way to investigate key drivers of compliance costs to see if judgments can be made about why and how *ex ante* and *ex post* estimates of costs differ. In addition to describing this conceptual framework, we describe the criteria used to select the rules to be analyzed, summarize the main hypotheses for why *ex ante* and *ex post* cost estimates may differ and discuss some of the challenges encountered in conducting these *ex post* analyses.

**Keywords:** cost analysis; environmental regulation; *ex post* comparisons; retrospective analysis.

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### 1 Introduction

The Office of Management and Budget has continually stressed the need for regulatory agencies to conduct “retrospective analyses.” In their *Draft Report to Congress on the Benefits and Costs of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities*, OMB states: “Retrospective analysis, required by Executive Order 13563 and institutionalized by Executive Order 13610, can be an important way of increasing accuracy” (OMB 2014). The Executive Orders instruct: “it is particularly important for agencies to conduct retrospective analy-

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ses of existing rules to examine whether they remain justified and whether they should be modified or streamlined in light of changed circumstances, including the rise of new technologies.”<sup>1</sup> Interestingly, when OMB uses the term “retrospective analyses,” they generally refer to reexamining the effectiveness and burden of a regulation in place.

Of course, this makes sense. Benefit-cost analyses (BCA) of environmental regulations most often involve integrating science from a wide array of disciplines. Engineering, contaminant fate and transport modeling, ecology, toxicology, epidemiology, exposure modeling, behavioral modeling and economic valuation methods are all needed to assess the benefits and costs of environmental regulations. All these sciences have advanced dramatically in the last decade. With these advances, agencies should periodically assess whether regulations are still appropriate in their current form. For example, EPA revisits National Ambient Air Quality Standards for each criteria air pollutant approximately every 5 years. Revisiting regulatory decisions to incorporate new science is critical and a great deal of effort is devoted to keeping current with scientific advances.

Another definition of retrospective analysis receives too little attention and is often confused with the former. Specifically, each BCA contains estimates of the *future* benefits and costs of a regulation. This second type of retrospective analysis compares the estimates of future or *ex ante* benefits and costs with the actual or *ex post* benefits and costs that resulted from the rule (or estimates of these actual benefits and costs based on more recent data.) While the need to update our analysis to reflect the most recent science is broadly acknowledged, very little work has been done examining how well *ex ante* BCAs estimate the actual benefits and costs of those regulations. Focusing on costs, the literature posits a number of hypotheses for why one might expect *ex ante* and *ex post* cost estimates to differ, yet *ex post* cost case studies are too few in number and too narrow in scope to lend strong support for one hypothesis over another. Existing case studies are often based on limited data and overlap in coverage, with many of the same regulations appearing in multiple publications.

For these reasons, EPA launched an effort to augment the existing literature with additional *ex post* evaluations of costs. Similar to previous studies, we examine the relationship between *ex ante* and *ex post* cost using a case study approach. However, we develop a common conceptual framework for our *ex post* cost assessments. This allows us to more consistently investigate the key drivers of compliance costs across regulations to see if informed judgments can be made

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<sup>1</sup> See E.O. 13610. “Identifying and Reducing Regulatory Burdens.” FR 77(93), May 14, 2012. (available at: [http://www.whitehouse.gov/sites/default/files/docs/microsites/omb/eo\\_13610\\_identifying\\_and\\_reducing\\_regulatory\\_burdens.pdf](http://www.whitehouse.gov/sites/default/files/docs/microsites/omb/eo_13610_identifying_and_reducing_regulatory_burdens.pdf)).

on the general accuracy of *ex ante* estimates and what underlying factors contribute to differences (or similarities) between *ex ante* and *ex post* estimates.

A careful assessment of *ex post* cost drivers could help identify systematic differences between *ex post* and *ex ante* compliance cost estimates and, ultimately, allow for improvements in the way in which *ex ante* analyses are done. For instance, if unanticipated changes in market conditions, energy prices, or available technologies regularly result in an over or underestimate of costs, EPA can invest in improving methods that better capture these effects on costs *ex ante*. It is also possible that industry overstates the expected costs of compliance (EPA often has to rely on industry to supply it with otherwise unavailable information on expected compliance costs).

Even if such specific differences between *ex ante* and *ex post* cost studies cannot be identified, a sizable set of retrospective analyses can offer broader insights, such as whether certain cost categories are particularly uncertain or how to better incorporate behavioral responses to regulation into *ex ante* analyses. This special issue of the *Journal of Benefit Cost Analysis* summarizes the findings of four case studies that examine the costs of five EPA regulations. We end with an article (Simpson) that attempts to test statistically if *ex ante* estimates are biased based on the published literature. His article points to a possible path forward using rigorous analytic techniques as more and better retrospective cost analyses become available.

The remaining sections are organized as follows. Section 2 reviews the reasons for underlying differences between *ex ante* and *ex post* cost estimates in the literature. Section 3 describes the conceptual framework we apply to structure each of the case studies, the rule selection process, and the *ex post* cost estimation strategies. Section 4 discusses lessons learned and challenges encountered in conducting the case studies. We end with a brief description of the articles included in this special issue.

## 2 Literature review of previous retrospective cost studies

A number of researchers have reviewed *ex ante* estimates of the costs of environmental and other forms of regulation in light of *ex post* estimates of such costs. We focus here largely on survey articles that review a number of individual studies, each of which have attempted to compare *ex ante* to *ex post* cost estimates, with the goal of trying to draw out more general lessons concerning the accuracy of the *ex ante* estimates. As these survey articles themselves often incorporate results

from a dozen or more individual studies, we should emphasize that the overall literature is significantly larger than one might infer simply from counting the number of papers we cite. We begin with a brief overview of the types of regulations that have been examined retrospectively as well as the general findings with regard to the accuracy of *ex ante* cost estimates. We then proceed to a discussion of the main reasons why *ex ante* costs may be under or overestimated based on this literature.

## 2.1 Overview of the survey articles

Table 1 summarizes over a dozen survey articles with regard to the types of regulations reviewed and general findings of accuracy. Most of the underlying studies focus on US regulations, with EPA regulations featured prominently. In a few cases *ex ante* estimates of the cost of regulation are available from both the regulator and industry, offering another point of comparison to *ex post* estimates. In general, *ex ante* cost estimates are more often found to overestimate than underestimate realized costs, and in cases where industry estimates are available it appears that the regulator is often more accurate in its assessments of costs *ex ante*.

While Table 1 may give the reader the impression that much work has already been done to evaluate the costs of regulation retrospectively, there are two reasons why this evidence is less compelling than it may appear. First, the paucity of *ex post* data on compliance costs and the large variation in methodology and scope of analysis produce estimates with large error bounds. Studies differ in the approaches they take to the estimation of *ex ante* costs, and the elements they include in such estimates. Some have considered only capital costs, others capital and operating costs. To the extent that the times at which costs are incurred differ across studies, differences in the discount rates their authors assume affect cost estimates. Moreover, analysts also have to apply their best judgment to distinguish costs that might be incurred in the course of business as usual from those that would need to be incurred to meet regulatory requirements. If, for example, the general trend in an industry is toward the availability of cleaner production technology over time, the cost associated with a regulation might best be measured as the incremental cost of accelerating capital replacement, rather than the total cost of a new capital investment. Analyses of the Title IV SO<sub>2</sub> cap-and-trade program tend to be the most analytically rigorous: boiler-level data on emissions, the price of permits, and methods of compliance utilized allow for the use of sophisticated econometric evaluation techniques.

Table 1 Summary of accuracy of *ex ante* costs from existing studies.

Authors (Date of Publication)	Description	Accuracy of <i>ex-ante</i> cost estimation
Putnam, Hayes, and Bartlett (1980)	Compared US EPA and industry <i>ex-ante</i> estimates of capital expenditures to actual expenditures for five EPA regulations promulgated from 1974–1977	In four of five cases, industry over-estimated costs. In three of five cases, EPA over-estimated costs
Jantzen (1989) and RIVM (2000) as reported in Oosterhuis et al. (2006)	Evaluated costs of compliance for eight regulations associated with the first Dutch National Environmental Plan of 1988	Costs were overestimated <i>ex ante</i> for five regulations, but only one <i>ex ante</i> estimate was as much as 2x the <i>ex post</i> estimate; in aggregate <i>ex ante</i> was only 13% higher than <i>ex post</i>
Office of Technology Assessment (1995)	Eight OSHA regulations promulgated from 1974 to 1989 in the chemical, service, and manufacturing industries	OSHA overestimated costs <i>ex ante</i> in every case. In two cases, costs may have been negative (i.e. resulted in cost savings)
Hodges (1997)	Compared industry <i>ex ante</i> estimates to <i>ex post</i> cost estimates for 12 US environmental and workplace safety regulations from the 1970s to 1990s	In every case evaluated, costs were overestimated <i>ex ante</i> ; in 11 of 12 cases, <i>ex ante</i> estimates were more than double <i>ex post</i> costs
Harrington, Morgenstern, and Nelson (2000)	28 US regulations promulgated by EPA, OSHA, and other regional and international regulators (13 were EPA regulations)	Total costs overestimated for 14, underestimated for three, and reasonably accurate (within $\pm 25\%$ ) for 11 regulations; unit costs overestimated as often as underestimated. (For EPA regulations, seven overestimated costs <i>ex ante</i> , two underestimated, and three reasonably accurate.)
Anderson and Sherwood (2002)	11 vehicle emission and six fuel-quality US EPA regulations	In most cases <i>ex ante</i> estimates of induced price increases overestimated actual changes; EPA estimates tended to be more accurate than industry
Thompson, Sequi-Gomez, and Graham (2002)	US consumer safety regulation requiring air bags in automobiles	Cost estimated were reasonably accurate: <i>ex ante</i> exceeded <i>ex post</i> cost estimates by <5%

(Table 1 Continued)

Authors (Date of Publication)	Description	Accuracy of ex-ante cost estimation
Grosse, Waitzman, Romano, and Mulinare (2005)	Evaluated the accuracy of 3 different <i>ex ante</i> studies of a US FDA regulation to fortify cereal grains with folic acid	<i>Ex ante</i> estimates overestimated costs by 3.5–9 times actual costs
OMB (2005)	47 US regulations initiated between 1976 and 1995 (18 EPA regulations)	Of 40 regulations for which data were available, 16 overestimated costs <i>ex ante</i> , 12 underestimated them, and 12 were reasonably accurate.
MacLeod, Moran, Aresti, Harrington, and Morgenstern (2006)	Eight UK regulations	Five overestimated costs <i>ex ante</i> , two underestimated, and one was reasonably accurate (within $\pm 25\%$ )
Oosterhuis et al. (2006) <sup>2</sup>	Five EU environmental regulations	Costs were overestimated <i>ex ante</i> by a factor of two or more in 4 cases, and reasonably accurate in 1 case
Dale, Antinori, McNeil, McMahon, and Fujita (2009)	Used a hedonic regression approach to evaluate <i>ex ante</i> costs of US DOE energy efficiency regulations on consumer appliances	<i>Ex ante</i> estimates over estimated costs
National Research Council (NRC) (2012)	Evaluated EPA's estimates of costs for a proposed EPA water regulation to establish nutrient criteria	Inconclusive since <i>ex post</i> data were not yet available
Chan, Stavins, Stowe, and Sweeney (2012)	Summarized evidence on cost, environmental effectiveness, distributional impacts, etc., of the SO <sub>2</sub> cap-and-trade under Title IV of the 1990 Clean Air Act Amendments	<i>Ex ante</i> estimates by EPA and industry vastly overestimated the actual cost of compliance.

<sup>2</sup> Oosterhuis et al. (2006) actually consider six environmental directives, addressing large combustion plants, integrated pollution prevention and control, ozone control, ozone depleting substances packaging, and nitrates, but are unable to develop *ex ante* compliance cost estimation numbers for the packaging directive.

Second, the collection of regulations for which any comparison of *ex ante* to *ex post* cost estimates has been performed is small and is unlikely to form a representative sample of the universe of environmental rules that have been promulgated. Many of the survey articles summarize the same sets of underlying studies, which means that there is substantial overlap. Among the rules that have been analyzed, there is reason to believe that those for which unforeseen technological breakthroughs occurred might be overrepresented because they are often the most celebrated and visible regulations. It is also likely that economists prefer to study regulations where regulated parties were given flexible options for compliance. Harrington et al. (2000) suggest that this is because more data are available for rules that establish markets, as prices are easily observed, and because “economists ... have a proprietary interest in the performance of economic incentives” (fn. 21, p. 306). For instance, a vast *ex-post* literature focused on the SO<sub>2</sub> cap-and-trade program under Title IV exists with Chan et al. (2012) being the latest summary available.

## 2.2 Why *ex ante* and *ex post* cost estimates may differ

There are many reasons that potentially explain why *ex post* and *ex ante* cost estimates might diverge. The extent to which the studies included in Table 1 reflect these reasons vary. They also vary with regard to the level of insight they provide on any particular cause for divergence. With these caveats in mind, we briefly summarize potential reasons *ex ante* and *ex post* costs may differ. We are particularly concerned with factors that might lead to *ex ante* cost estimates being systematically too high (or too low), as opposed to those that would result in their being less accurate while still, on average, correct.

### 2.2.1 Strategic factors affecting *ex ante* costs

*Ex ante* cost estimates are typically based on the application of existing technologies and the best source for information about existing technologies is the people who use them. Much of the cost information used in regulatory analyses comes directly from industry (Bailey, Haq, & Goudson, 2002; Harrington et al., 2000; Hodges, 1997). Regulators must typically elicit outsiders' perceptions of compliance costs, because the regulators themselves have limited expertise. It is not uncommon for EPA to solicit industry compliance cost data through surveys of individual firms or through interactions with their trade organizations (Harrington et al., 2000). This is unavoidable because industry sources generally have the best information concerning compliance costs. In using these data,

regulators assume that industry is providing the best available information for least cost solutions.

The problem is that industry may also have an incentive to slant that information in self-serving ways (see Bailey et al., 2002, and more generally, Sappington and Stiglitz, 1987). When asked for input on costs of compliance, industry is likely to respond by describing a plausible way of complying rather than by evaluating all alternatives before identifying that which will minimize their compliance costs. Harrington et al. (2000) suggest that firms are more likely to describe “off-the-shelf” technologies in their cost estimates instead of examining opportunities for innovation.

Regulated entities may overstate their costs of compliance (Bailey et al., 2002; Hodges, 1997; MacLeod et al., 2006) in an attempt to thwart what they see as onerous regulations by providing a signal that costs are prohibitive.<sup>3</sup> An alternate explanation may be that industry is providing conservative estimates given the numerous uncertainties associated with regulations (Oosterhuis et al., 2006). Bailey et al. (2002) suggest that firms may “attempt to shape the regulations in ways that would minimize the costs of compliance” (p.251), though this could mean that they attempt to shape both the stringency and the flexibility of the standards imposed on them. It is therefore problematic, albeit practically unavoidable, that “industry is the source, directly or indirectly, of most of the data used to support cost estimates” by EPA (Harrington et al., 2000, p. 20). Conversely, agents providing cost information may have other motivations. Boardman, Mallery, and Vining (1994) study the accuracy of *ex ante* cost estimates for a road-building project and find that costs were underestimated. The direction of the bias is readily explained by the fact that in road-building, private firms profit from public construction activities and so would want to make such activities seem more attractive by understating costs.<sup>4</sup>

Environmental regulation might impose a restraint on the competition that can arise when some firms cannot operate as cleanly as others. Salop and Scheffman’s (1983) depiction of “raising rivals’ costs” could provide a rationale for why some firms would prefer regulation that would increase their own level of regulation because it would hurt others more. Maloney and McCormick (1982) argue

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<sup>3</sup> Bailey et al. (2002) make an interesting related observation: in addition to overstating costs, industry groups may also question the benefits of a proposed regulation.

<sup>4</sup> Other studies of the accuracy of estimates of the costs and benefits of public programs include Dayton (1998) on HIV/AIDS intervention, Rideout and Omi (1995) on fuel reduction measures in public forests, Lindner and Jarrett (1978) on publically sponsored research, LaFrance and de Gorter (1985) on dairy price supports, and, very generally, Sappington and Stiglitz (1987) on privatization.

that tighter OSHA regulation of cotton dust and EPA regulations to prevent significant deterioration near existing factories both had the effect of restricting new competition and enhancing the profits of incumbent firms that were well suited to avoid the impact of the regulations or exempt them from meeting it.<sup>5</sup>

A related concern may be that a regulatory agency may be less rigorous in estimating the costs of rules that appear likely to pass a benefit-cost test. Under such circumstances there may be reduced incentive for regulators to refine their cost estimates or to investigate alternative pathways to compliance, such as process changes or alternative technologies. Further, regulators might conservatively overstate costs in cases when affordability criteria must be met on the grounds that if a regulation is found to be affordable when stated costs are higher than expected, the regulation will be affordable using more refined estimates of costs as well. Harrington et al. (2000) noted that EPA provided upper bound cost estimates in their effluent guidelines program. It might also be counterproductive for regulators to develop more refined cost estimates if they expect that the regulated industry would argue against their use in subsequent rule-makings.

In addition to the technologies regulators assume when predicting the costs of regulation, they also typically make assumptions concerning compliance and coverage. While it is common to assume full compliance with a proposed rule, actual compliance may be less-than-perfect. Although it is now dated, Putnam et al. (1980) found compliance rates of only 54% in the iron and steel industry and 83% in petroleum. MacLeod et al. (2006) cite imperfect compliance as one reason for finding costs overestimated in *ex ante* studies.

A related consideration concerns the regulators' assumptions about baselines. EPA's *Guidelines for Preparing Economic Analyses* (2010) instructs analysts to compare the benefits and costs of regulations relative to "a reference point that reflects the world without the regulation" (p. 5-1). Some authors have suggested that regulatory agencies have their own strategic objectives which could, in theory, lead to incentives both to overstate the benefits and understate the costs of regulation (James, 1998; Hahn, 1996; Harrington et al., 2000; MacLeod et al., 2006; OMB, 1998). Harrington et al. (2000) find that agencies may overstate the baseline but that the data do not support a purposeful underestimation of costs per se. Moreover, there may be limits to the ability of agencies to pursue cost underestimation. Industry groups with relatively concentrated membership and relatively closely aligned interests are likely to challenge unrealistically low estimates.

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<sup>5</sup> See Adler (1996) and Bailey et al. (2002) for other examples.

### 2.2.2 Technological innovation and unforeseen compliance options

As Bailey et al. (2002) write, “*Ex ante* estimates are forecasts and, like all forecasts, their accuracy will be limited due to uncertainty” (p. 255). There are a number of potential sources of uncertainty. Perhaps the most prominent concerns prospects for the development of new technology to meet regulatory requirements. Almost all earlier literature surveys highlight that *ex ante* estimates of the cost of regulation do not carefully consider the role of innovation, or more broadly, the full range of options open to regulated entities in complying with tighter standards.

Environmental regulations are recognized in the literature as one possible factor among many that may induce innovation (e.g., Popp, Jaffe, & Newell, 2010). When firms are forced to rethink production processes and become more efficient, the result may be both environmental improvement and competitive advantage (Heinzerling & Ackerman, 2002; Porter, 1991). While it is a recognized best practice to at least attempt to factor learning into estimates of the costs of regulation (EPA 2010), analysts often do not incorporate potential technological innovation into *ex ante* cost estimates. Even if they do put in their best estimates of future technological improvements, there would still be random variation in how quickly or completely such improvements are realized.

Different assumptions concerning technological progress, requirements arising from regulations other than those under consideration in the analysis, and market conditions could all affect the estimated cost of regulations. For instance, when EPA estimated the costs of its Enhanced Inspection and Maintenance program for automobiles, analysts assumed a high level of effectiveness of repairs and incorporation of 56 million cars into the program. After implementation, it was determined that the repairs were less effective at reducing emissions than EPA analysts assumed. Only four states actually implemented the program (Harrington et al., 2000).

There are numerous cases where technological innovation following a new regulation was underestimated. In EPA’s Chlorofluorocarbon (CFC) Rule, for example, the *ex post* costs of the CFC phase-out were 30% less than the *ex ante* estimates, even though an expedited phase-out occurred (Hodges, 1997). Analysts estimating costs prior to the CFC phase-out’s implementation did not account for process changes, reliance on blends of chemicals, and substitutes (e.g., existing hydrofluorocarbons or HFCs) that led to lower-than-expected compliance costs. Although estimates suggested that substitutes would be unavailable for almost a decade, industrial efforts led to their availability after about 2 years (Harrington et al., 2000; Hodges, 1997).<sup>6</sup>

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<sup>6</sup> CFC-12, used in refrigeration, was replaced with HFC-134a, an existing chemical used in automobile air conditioners starting back in 1991. Use of CFC-113 in foam-blowing applications has

As another example, cost estimates prior to the implementation of the SO<sub>2</sub> cap-and-trade program under Title IV of the 1990 Clean Air Act Amendments (CAAA) failed to predict technological and process evolution that lowered compliance costs considerably. Original estimates predicted compliance costs between \$4 billion and \$5 billion per year (Hodges, 1997). In the *ex ante* analysis, scrubbers, the SO<sub>2</sub> treatment technology, were assumed to be less efficient than *ex post* studies show (Harrington et al., 2000). Moreover, Popp (2003) concluded that Title IV, which was designed to provide incentives to install scrubbers with higher removal efficiencies, was successful in promoting the introduction of higher efficiency scrubbers into the market, thereby leading to lower operating costs. The *ex ante* analysis also did not account for fuel mixing, the blending of low and high sulfur coal, that lowered sulfur dioxide emissions (Harrington et al., 2000). At the time of the estimates, blending fuels seemed impractical (Hodges, 1997).

Finally, it makes sense to suppose that technological innovation is more likely to occur in response to regulations that affect a large number of facilities. Developing an improved technology is a fixed cost, and so investment in such technologies will be more attractive the greater the number of production units and cost savings over which it can be amortized. Additionally, data are more likely to be available for rules that affect larger industries than smaller ones because regulatory impact analyses are unlikely even to be performed if total economic effect is predicted to be <\$100 million. This difference creates another potential source of selection bias.

### 2.2.3 Unanticipated exogenous changes

Even an analysis that is reasonably accurate at the time it was prepared may be well wide of the mark by the time the rule actually enters into force. Regulatory processes are often subject to significant amendment and delay. In 2006, the average action development time for rules requiring benefit-cost analyses was nearly 3 years.<sup>7</sup> Even if we confine our attention to the period between the proposal of a regulation and the publication of a final rule, Kerwin and Furlong (1992) found that 523 days elapse on average. Thus, cost estimates based on early versions of a rule may no longer apply to the rule that eventually emerges (see Harrington et al., 2000; Morgenstern & Landy, 1997; Putnam et al., 1980; and

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been replaced by HFC, a substitute; additionally, process changes and chemical blends were essential to decreased consumption of CFC-113 (Harrington et al., 2000).

<sup>7</sup> See [http://www.epa.gov/regstat/development\\_time\\_office2.html](http://www.epa.gov/regstat/development_time_office2.html).

Oosterhuis et al., 2006, who note a similar tendency in European regulation).<sup>8</sup> Also, promulgated regulations often phase in requirements to allow firms time to comply, which sometimes affords them the time to develop lower-cost options that were not known when the regulatory analysis was conducted. Such possibilities are illustrated by the CFC regulation. While the CFC rule was under development, industry researched alternatives. After substitutes and new practices were identified, firms faced costs that were lower than those anticipated *ex ante* (Hammit, 2000; Harrington et al., 2000).

Unanticipated factors indirectly linked to the rules may lower their costs. In the case of Title IV, for example, deregulation in the railroad industry allowed for unanticipated low-cost shipping of low sulfur coals from the Powder River Basin in Wyoming to the East (Busse & Keohane, 2007; Hodges, 1997). This reduction in the price of low-sulfur coal, coupled with low-cost technological improvements, reduced compliance costs for electric utilities in the East (Burtraw & Palmer, 2004; Busse & Keohane, 2007; Carlson, Burtraw, Cropper, & Palmer, 2000; Harrington et al., 2000; Hodges, 1997).<sup>9</sup>

## 3 Methodology

### 3.1 Conceptual framework for *ex post* cost assessment

Unlike much of the previous literature, we develop a standardized framework to identify systematically the key components of compliance costs relevant to a rule, to assess whether each of the components turned out to be larger or smaller than the *ex ante* estimate, and to understand the characteristics of the regulation that influenced the divergence. While the aim here is not to produce *ex post* cost estimates or reproduce the *ex ante* estimates using the same level of rigor employed

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**8** Other authors suggest that such delay may be part of the design of the regulatory process. Bailey et al. (2002) describe the process of regulatory development in the European Union as a sort of extended negotiation between regulators and the firms they oversee, with each staking out negotiating positions from which they expect to be budged over time. This may, however, represent a distinction between European and US practice, the latter of which they characterize as “adversarial and legalistic.”

**9** To give another example Joskow (1988) argued that electric utilities entered into long-term contracts with coal providers because the need for a specific grade of coal made for an obligate relationship between a mine and a plant. As it turned out, this relationship was not nearly as restrictive as had been thought in many cases.

in the Regulatory Impact Analyses, our intent is to glean enough information on the drivers of compliance cost to make a weight of evidence determination of the direction of our *ex ante* estimates – were they likely too high, too low, or about right? – and to identify underlying factors that contribute to differences (or similarities) between *ex ante* and *ex post* costs.

The degree to which an *ex post* evaluation of the costs of regulation is able to determine the accuracy of the initial assessment by EPA will vary by rule. We focus the *ex post* evaluation on costs that, if incorrect, could fundamentally alter the findings of the *ex ante* cost assessment. In line with the review of the existing literature, the scope of the *ex post* analysis is informed by a brief review of the *ex ante* cost assessment to identify:

- *The main drivers of costs ex-ante:* If these drivers were misidentified, then *ex ante* cost estimates might be flawed.
- *The main sources of uncertainty in estimating costs ex-ante:* The less that was known with certainty, the less accurate we would expect cost estimates to be.
- *Unanticipated exogenous changes that occurred after completion of the ex-ante analysis that have significant implications for the costs of the rule:* If the “state of the world” changed in unpredicted, or perhaps unpredictable, ways, then estimates would again be less accurate.

Sources of uncertainty are often rule specific but may include: lack of knowledge about who is in the regulated universe; lack of knowledge about the effectiveness of certain types of control technologies or processes in reducing pollutants; lack of information about the costs of relatively untried control technologies or processes; behavioral responses by industry or consumers to changing rules or incentives, including the possibility of non-compliance (NRC, 2012). In general, we maintain a timeline for implementation consistent with *ex ante* assumptions. However, in some cases there is uncertainty as to when regulated entities begin to undertake investment to comply with the rule. Thus, baseline assumptions may themselves be a source of uncertainty.

Exogenous changes are often difficult to anticipate *ex ante* but may have significant implications for the cost of meeting rule requirements. Examples include unrelated changes in market demand, higher than expected oil prices, industry-wide changes in manufacturing processes (unrelated to the rule), and other regulations, legal or political decisions that occurred concurrent with or after the *ex-ante* assessment took place but affected rule implementation.

Using the information gleaned from a review of the *ex ante* analysis, we proceed to an *ex post* assessment of costs. For each regulation analyzed, we first provide a narrative that summarizes the basic impetus and timeline for the rule. Second, we evaluate likely drivers of identified differences between *ex ante* and

*ex post* cost estimates using a broad categorization of cost components consistent with EPA's *Guidelines for Preparing Economic Analyses* (2010). Table 2 summarizes the key components of the cost analysis and the main questions we pose as part of the *ex post* assessment.

To evaluate unit compliance costs, we combine information about direct costs per unit of abatement (*direct compliance costs*) associated with each identified method of compliance (*methods of compliance*) plus any additional indirect compliance costs per unit of abatement (*indirect compliance costs*). When possible, we also offer an assessment of total compliance costs. To do this, we assess whether EPA correctly identified who has to comply (*regulated universe*), netting out any facilities already in compliance (*baseline*). While ideally we would measure the social cost of regulation (i.e., the sum of all opportunity costs incurred), most *ex ante* regulatory analyses only quantify compliance costs. As such, the first five components of the conceptual framework in Table 2 focus on the basic components for quantifying compliance costs. The final component (*opportunity costs*) leaves open the possibility of broader *ex post* evaluation of social cost when possible.

For each case study, we provide a summary of our assessment by cost component using a common table format to make it easy to understand how the *ex ante* and *ex post* costs compare and to aid the reader in making comparisons across case studies. However, while we strive for consistency across the case studies, sub-categories are sometimes modified to reflect unique aspects of a particular rule.

## 3.2 Selection of rules

To select the five rules for the case studies presented here, we first assembled an inventory of all EPA regulations coded in the Agency's Rule and Policy Information and Development System (RAPIDS) database as "economically significant" and promulgated since January 1995. Although it has since been replaced by a new system, RAPIDS was at the time the Agency's tracking database for regulatory and significant non-regulatory actions.<sup>10</sup> Typically, these are actions that involve notice and comment rulemaking, or are major work products that require significant cross-Agency collaboration. We focus on recent regulations because rules promulgated decades ago likely have been overridden by new regulations,

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<sup>10</sup> In February 2012, RAPIDS was replaced by ADP TRACKER as the system EPA uses to track its Action Development Process.

**Table 2** Summary of conceptual framework to guide *ex post* cost assessment.

Cost component	Assessment questions posed
Regulated universe	What types of entities are required to comply with the rule? How many entities of each type are required to comply?
Baseline	To what extent are these technologies already in use prior to the rule?
Methods of compliance	What types of technologies or methods are used to comply? How often are these compliance strategies used?
Direct compliance costs	What are the initial or one-time compliance costs (fixed or variable components)? What are the ongoing compliance costs (operation and maintenance)?
Indirect compliance costs	What are the indirect compliance costs (e.g., quality trade-offs)?
Opportunity costs	Are there other major opportunity costs associated with the rule (for instance, in related markets)?

making it more difficult to isolate the compliance strategies and costs associated with the old rule. Furthermore, the lessons learned from examining older regulations may be less relevant going forward because of advances in benefit-cost analysis methodologies that have been adopted since that time.

The RAPIDS search generated a list of 111 entries. We reviewed the list and gathered preliminary information on each rule (e.g., compliance dates) to determine which rules could feasibly be studied. We discarded any duplicate entries and rules that were:

- 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).

To that list, we added effluent limitation guidelines, a category of rules that routinely undergoes OMB review for which detailed cost analyses are produced. The resulting eligible inventory consists of 42 rules promulgated between 1995 and 2005. (Note that this number does not include chemical actions, which are not tracked in the RAPIDS database.) We circulated this list to EPA program offices

for their feedback to ensure that there were no inadvertent omissions or rules that should not be included.

The five rules presented in this special issue were selected to serve as pilot case studies to help us understand which methodologies are most appropriate to measure *ex post* compliance costs for a range of rules. Therefore, these five rules were not chosen randomly, but rather were chosen to cover various media, source categories, and types of regulations (e.g., performance standard versus prescriptive regulation). Four of the rules were taken from the master list of 42 rules and the fifth is a critical use exemption nomination of a fumigant identified by the Office of Pesticides Program (OPP) as a good candidate for study due to the likely availability of data. The five regulations evaluated in this report are as follows:

- The 2001/2004 National Emission Standards for Hazardous Air Pollutants and Effluent Limitations Guidelines, Pretreatment Standards for Pulp and Paper (The Cluster Rule),
- New Source Performance Standards on the Pulp and Paper industry (MACT II);
- Critical Use Exemptions for Use of Methyl Bromide for Growing Open Field Fresh Strawberries in California for the 2006–2010 seasons;
- The 2001 National Primary Drinking Water Regulations for Arsenic; and
- The 1998 Locomotive Emission Standards.

## 4 Lessons learned and next steps

The four case studies presented in this special issue represent only the first step in generating a larger body of evidence on how well the EPA estimates the costs of regulation *ex ante*. While individual case studies of particular regulations are informative, perhaps the more significant contribution of this special issue is the application of a common conceptual framework to the *ex-post* assessments. However, applying this framework to our case studies underscores the difficulties and impediments to conducting consistent, comprehensive retrospective analyses of regulatory costs. As an example, our analyses were often limited by the paucity of evidence on how facilities chose to comply with the selected regulations and their resulting costs. In short, all of the case studies suffer from a lack of comprehensive cost information on treatment technologies and mitigation strategies at the facility level, limiting our ability to make definitive statements on the reasons for differences between *ex ante* and *ex post* cost estimates. Instead, the case studies either rely on accessible industry level data (as opposed to facility level data), bottom-up cost estimates for a typical “model” facility, or information from a limited number of industry experts. Each of these approaches, while useful, also met with its own problems. For some case studies, the arsenic rule

in particular, the regulated sources were quite heterogeneous, varying by size, attributes, compliance technology, and vintage, giving rise to complicated decision strategies for identifying appropriate technologies.

Disentangling the expenditures made expressly for pollution control was a challenge for several of the case studies. Compliance expenditure data sometimes include expenditures referred to as “might as well do this” costs, those costs that occur at the same time as the compliance costs but that are in truth unrelated to the regulation (i.e., upgrades, maintenance, etc.). For others, namely the pulp and paper rules and the locomotive rule, defining the counterfactual was difficult (i.e. what would have occurred had the rule not been promulgated).

It also proved challenging to find industry experts in some cases. Qualified experts were sometimes few in number to begin with, making it particularly difficult to identify individuals who had not offered expertise during the development of the rule. In reaching out to trade associations for assistance, we found that some were helpful but others were reluctant to become involved.

To be sure, conducting *ex post* analyses proved more challenging than originally anticipated, and, while informative, the added evidence provided by these four case studies is insufficient to draw broad conclusions about EPA cost estimation practices. As already noted, the rules discussed here were not selected to be representative but rather were selected to shed light on the process of conducting *ex post* analyses and the challenges analysts engaged in these activities may face. Going forward, additional rules will be selected using a stratified random selection process. As we pursue additional case studies, we will continue to explore the feasibility of other data collection strategies including site visits, focus groups, and industry surveys to augment the publically available information we are able to identify. Eventually, EPA hopes to amass enough information to analyze statistically the strength of the hypotheses that explain the divergence between *ex ante* and *ex post* cost estimation with the ultimate goal of informing improvements to our cost estimation methodologies.

## 5 The special issue

The first four articles in this special issue present the *ex post* assessments of five EPA rules. The fifth article in this issue proposes a regression-based test of the bias of *ex ante* compliance cost estimates (Simpson).

Various methodologies exist for collecting *ex post* information, ranging from using publically available data sources, reaching out to industry compliance experts, conducting site visits to facilities, or administering a comprehensive

industry survey. In each case study, we evaluate the feasibility of each of these information collection strategies. While each case study uses publically available data to some extent, only Wolverton relies on publically available data exclusively. All others augment the publically available data with information gathered from industry experts on compliance strategies and *ex post* cost. Industry surveys and site visits were not pursued for any of the case studies.

Despite the challenges encountered in conducting the *ex post* assessments of these five EPA regulations, these case studies make an important contribution to the evaluation of not only the accuracy of *ex ante* estimates, but the drivers of differences in *ex ante* and *ex post* costs. Morgan, Pasurka and Shadbegian examine the Cluster Rule and the MACT II Rule together because they both apply to pulp and paper mills over roughly the same time period. The Cluster Rule is a set of integrated air and water rulemakings that were published in 1998 while the MACT II rule, promulgated in 2001, regulates chemical recovery combustion sources. A key finding from the *ex post* assessment for these rules is that there is a high level of uncertainty about the baseline, both when mills began to comply with the regulations and whether certain technologies were adopted prior to the rule in response to community pressure. It also appears that EPA underestimated the use of the compliance flexibilities made available to mills under the rules.

Using *ex post* information on open field fresh strawberries in California for the 2006–2010 growing season, Wolverton finds that the impact of the critical use exemptions of methyl bromide (MBr) on farmers was likely less than expected because of the availability and viability of MBr alternatives. Switching to these MBr alternatives appears to have had little effect on strawberry yield. However, *ex-post* evaluation also confirms the effect of California regulatory restrictions in limiting the use of various economically competitive alternatives. It is also worth noting that unanticipated complications after switching away from methyl bromide, such as new diseases, have slowed the transition to MBr alternatives.

Morgan and Simon also find that iron-based adsorption media, an alternative to the best available technologies evaluated by EPA, was widely used by water systems as an arsenic mitigation strategy to comply with the Arsenic Rule. While EPA was aware of this technology at the time of the rule, the technology was still in the pilot and research phase so it was not included in the *ex ante* analysis. Water systems also found non-technology options as a viable way to comply with the arsenic standard.

Relying mainly on industry expert opinion, Kopits finds that the total cost of bringing line-haul locomotives into compliance with the 1998 Locomotive Emission Standards rule remains uncertain. Even though the initial per-unit locomotive compliance costs were higher than predicted by EPA, total costs also depend on the number of locomotives affected by the regulation. 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.

As Simpson points out in the final article of this special issue, despite the existence of a number of articles in the literature reporting *ex ante* and *ex post* compliance cost estimates, it is surprisingly difficult to get a large sample of such comparisons. Even though Simpson proposes a regression-based test of the bias of *ex ante* compliance cost estimates, and cannot reject the hypothesis that estimates are unbiased, he also emphasizes that his results arise from consideration of a small and heterogeneous data set. His most salient finding does not concern the bias of *ex ante* cost estimates so much as their inaccuracy and the continuing paucity of careful studies.

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