# On the Accuracy of Regulatory Cost Estimates

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**Abstract**

This study compares *ex ante* estimates of the direct costs of individual regulations to *ex post* assessments of the same regulations. Our review of more than two dozen environmental and occupational safety regulations indicates that ex *ante* estimates of total (direct) costs have tended to exceed actuals. We find this to be true of 12 of the 25 rules in our data set, while for only 6 were the *ex ante* estimates too low. The overestimation of total costs is often due to errors in the quantity of emission reductions achieved by the rule which, in turn, suggest that the rule's benefits may also be overestimated. The quantity errors are driven by both baseline and compliance issues. At least for EPA and OSHA rules, overestimation of *per-unit* abatement costs occurs about as often as underestimation. In contrast, for those rules that use economic incentives, per-unit costs are consistently overestimated.

Much of the overestimation can be attributed to technical innovations unanticipated at the time the rule is issued, and to quantity errors. In addition, several methodological and procedural explanations also apply: changes in the regulation after the cost estimate is prepared, use of maximum cost estimates, and asymmetric error correction.

Since a number of environmental laws encourage the development of cost estimates that reflect a maximum rather than a mean, regulatory agencies could issue a "best estimate" along with the statutorily preferred cost estimate. Likewise, they could ensure that rule changes made in the course of the regulatory development process are manifest in revised cost estimates. Indeed, discovering how and when to adjust *ex ante* estimates provides the strongest possible justification for more credible *ex post* studies--a research activity that merits greater emphasis.

Key Words: environmental costs, costing accuracy, innovation and regulation

JEL Classification Numbers: D82, K23, Q28

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## I. INTRODUCTION

Reflecting increasing concerns about the accuracy of cost estimates of environmental and occupational safety regulations, the Office of Management and Budget (1998) recently observed that, "industry representatives and think tanks assert…that [government] estimates understate costs…while public interest groups and Federal agencies generally assert…that [government] estimates overstate costs." A great deal of debate has focused on the normative question of how (if at all) cost information should be used in regulatory decision-making. Curiously, though, beyond the occasional anecdotes, little serious attention has been devoted to assessing the overall accuracy of the cost information that is generated by and available to regulators. Is there evidence of systematic errors in these so-called *ex ante* cost estimates? If so, are the estimates too high or too low? What lessons are suggested for reform of rulemaking processes?

There is an interesting ideological divide in the types of evidence brought to bear in addressing these questions. Those who believe costs are underestimated often have in mind the costs of an entire program or legislative initiative. Superfund is Exhibit A. Critics argue that the program, originally designed to clean up Love Canal and a few other big sites, expanded its scope and became a "behemoth, towering over American environmental policy" (Cairncross, 1993). Other critics have focused on the discrepancy between the initial objectives of U.S. environmental laws, e.g., the Clean Air Act (1970), and the progress toward meeting those objectives (Downing and Brady, 1980). The National Ambient Air Quality Standards, for example, were originally thought to be achievable within a decade. Yet, even today we still are still unsure how, when, or even if the original goals will be met.

Another argument made by those who believe costs are understated is that the *ex ante* estimates leave out some important cost categories, e.g., regulatory-induced job losses, claims on management attention, discouraged investment, and retarded innovation. Dynamic general equilibrium analyses, which attempt to account for the indirect effects of price increases in one sector of the U.S. economy on purchasing and production decisions throughout the

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economy, suggest that the long run social costs of regulation exceed direct compliance expenditures by 30-50 percent (Hazilla and Kopp, 1990; Jorgenson and Wilcoxen, 1990). However, such models are not generally used in analyses of individual regulations.

In contrast to such concerns, those who believe costs are overestimated prefer to look at the direct costs of complying with specific regulations. The most often cited example involves reductions of sulfur dioxide emissions mandated under the Clean Air Act Amendments (1990). In that case, the huge discrepancy between the early industry cost estimates (as high as $1500 per ton) and recent allowance prices (currently about $150 per ton, up from $75 per ton in 1997), is taken as evidence of a problem of government overestimates (e.g., Browner, 1997). Particularly in the environmental community, unforeseen innovations are credited with driving down the costs.

In this paper we avoid the broader and more contentious question of whether environmental programs grow far beyond their initial legislative intent: That issue is more difficult to deal with, in part because of the challenge of even stating the question in an empirically testable way. We also avoid the question of indirect costs, largely because of the inability to obtain *ex post* (or *ex ante*) cost information for individual regulations. Although claims that regulatory costs are overestimated do not always distinguish between agency and industry estimates, we consider industry estimates only as possible influences on agency forecasts, rather than as *per se* estimates of *ex ante* costs.

While finding bias in the cost estimates from industry (or environmental) sources is perhaps to be expected, the existence of systematic errors in cost estimates prepared by the regulatory agency itself has potentially significant implications. If costs are regularly overestimated, thereby making potential new regulations appear more costly, rulemakings would generally favor the selection of less stringent emission control options (and, conversely, if costs are consistently underestimated). Large discrepancies would lead not only to bad decisions, but would misrepresent the true burden of regulation on the society and undermine the public confidence in the regulatory process. Not surprisingly, the belief held by many environmentalists that costs tend to be overestimated (and benefits underestimated) by regulatory agencies underlies many of their concerns about allowing cost information, and particularly benefit-cost analysis, to play a prominent role in regulatory decisions. The only sure way of assessing systematic errors in regulatory cost estimates is to compare *ex ante* cost estimates, prepared at the time the regulation is issued, with actual costs, determined *ex post*. However, *ex post* studies of the costs of regulation are quite scarce in the literature on regulatory policy assessment. Rulemaking agencies have neither a legislative mandate nor a bureaucratic incentive to perform such analyses.[2] In fact, the conduct of *ex post* studies may detract from an agency's mission not only by using limited resources, but by generating

[2] Recently Congress has shown greater interest in *ex post* information. For example, the Clean Air Act Amendments (1990) required EPA to develop a retrospective assessment of the overall benefits and costs of the first twenty years of the Act.

outcomes that may prove embarrassing. Not surprisingly, most detailed *ex post* studies have been carried out by independent researchers.

While uncommon, some interesting and useful *ex post* estimates of the cost of environmental health and safety regulation have been prepared. In our examination of these studies we find evidence of both underestimation and overestimation, although overestimation appears in our sample to be more common. At least for national regulations in the U.S., the overestimation of total costs is often caused by forecasting errors in the quantity of emission reductions achieved by the rule. This, in turn, suggests that the benefits of the rule may also be overstated. In addition, much of the overestimation can be attributed to technical innovations unanticipated at the time the rule is issued. However, we also find that costs can be mis-estimated--and usually overestimated--for other reasons. Sometimes there are simply errors of analysis. Sometimes the cost estimate is not intended to be an accurate estimate of costs, but an upper bound of what the costs could be. And sometimes the regulation as implemented is not the same as the regulatory proposal for which the cost estimate was prepared.

The plan of the paper is as follows. Section II reviews the limited literature on the subject. Section III defines some key terms and presents an analytical framework for thinking about *ex ante/ex post* comparisons. Section IV surveys the results of those comparisons. Section V develops some possible explanations for our findings. Section VI presents our conclusions and directions for further research.

## II. LITERATURE REVIEW

It is a little surprising that so many observers believe that regulatory cost estimates overestimate the true costs of regulation, considering that costs of other government activities, especially procurement and public investment, are usually thought to be *under*estimated. "Government cost overruns" are famously the staple of headlines and talk shows, whether the government in question is local (stadiums or convention centers), state (expressways) or national (defense projects). The accuracy of *ex ante* cost estimates in government contracting has been studied more thoroughly than in rulemaking and is therefore a good place to start.

Several historical accounts of public investment projects have found government cost overruns to be deliberate and strategic. Caro (1974), for example, documents the legendary practices of Robert Moses, bureaucrat extraordinaire, whose public works projects transformed New York City (and State) between the 1920s and 1960s. Moses is said to have routinely and purposely underestimated the costs of major public works projects in order to gain quick approval. Once construction got underway he would re-estimate costs (usually multiplying them several-fold) and seek supplemental funding for the partially completed projects. According to Caro, Moses was such a powerful and persuasive figure that he was able repeatedly to sell ridiculously low project cost estimates to gullible legislators, who were then committed to the project and later too embarrassed to admit their gullibility. An even more striking example is provided by McCullough's (1978) account of the disastrous French attempt to build an ocean-connecting canal in Panama in the 1880s. Costs were honestly underestimated initially because French engineers, misled by their Suez experience, failed utterly to understand the magnitude of their task. As the true scope of the project became known, however, the leaders of the quasi-public corporation established to build and operate the canal refused to revise the costs or acknowledge the difficulties, for fear of causing a collapse in the stock price, leading to the financial embarrassment of the early backers of the project, especially its biggest backer, the French government.

More systematic attempts to analyze cost overruns have also focused on strategic explanations. These efforts have been concentrated in the study of defense contracting, where several analytical models have been developed to explain what Quirk and Terasawa (1984) call the "pervasive and massive" cost escalation in defense projects and in "first-of-a-kind" projects in the private sector. The explanations have focused on the difference between the competitive environment in which the cost estimate is made and the principal-agent environment that applies subsequently. For many years it was common for the Defense Department to issue cost-plus fixed fee contracts, which create obvious moral hazard problems. However, it has also been shown that inefficiencies and hence a tendency toward cost escalation can arise whenever perfect monitoring is not possible and contractors are risk-averse, regardless of the form of contract (Harris and Raviv, 1979; Weitzman, 1980).

A non-defense example of strategic cost underestimation can be found in federal support for local transit projects, which one observer attributes largely to the perverse incentives in the funding mechanism. In the eight U.S. cities examined Pickrell (1992) found that local officials "grossly" overestimated rail transit ridership and underestimated rail construction costs and operating expenses, thereby favoring large projects over less capital-intensive options. He concluded that such large errors were not simply technical mistakes but rather arise from the peculiar nature of federal transportation subsidies which favor capital-intensive projects such as fixed rail over buses and other more flexible systems.

Researchers have also found non-strategic reasons for cost escalation in government contracting. For example, Terasawa, Quirk and Womar (1984) show that cost escalation results under conditions of "turbulence," (mean-preserving increases in the variance of the production schedule). Such conditions are common in military procurement, since the annual defense budget is subject to frequent alteration in Congress.

Another source of nonstrategic systematic error is the "winner's curse," which can produce cost underestimates even without turbulence and even when analysts are trying to provide honest estimates of cost (Quirk and Terasawa, 1986). The authors assume a project consisting of components each chosen from a menu of possibilities, with a cost estimate attached to each possible component. Even if the costs of individual components are estimated without bias, the cost of the overall project is more likely to be underestimated because the individual component cost estimates are used to select the components of the combined project. Those components with underestimated costs are the ones more likely to make up the final project. The greater the uncertainty, furthermore, the larger the overall underestimation.

Finally, it is worth noting that cost underestimation is not inevitable in public investments. In a comparison of realized and forecast construction costs of federal water projects, Haveman (1972) shows substantial variation and a tendency toward overestimating costs. He attributes the overestimation to conceptual errors and inadequate forecasts of exogenous factors such as stream flows, with no reference to strategic bias by the estimators.

This quick survey of cost escalation in public investments may seem remote from our concerns about estimating the cost of regulation, but it offers at least three useful insights and one puzzle, we believe. First, it calls attention to the very great difference between the cooperative game being played by the agency and its contractors and the non-cooperative game (usually) being played by the agency and its regulatees. In the former case the parties may differ on many things, but they share a common interest in expanding the size of the program and in keeping public attention away from escalating costs. In the latter case, the regulatory agency may desire larger programs, but the regulatees usually do not, leading often to public complaints when costs are underestimated.

Second, for those regulatory programs that are also public investments, such as Superfund cleanup expenditures or federal subsidies for publicly-owned wastewater treatment facilities, costs are more likely to be underestimated than for other regulatory programs (CBO, 1994). Third, we see no reason why the nonstrategic explanations for cost underestimation in investment projects--cost turbulence and selection bias--should not in principle apply to regulatory cost estimation as well. Finally, the puzzle: If advances in technology operate so powerfully and conspicuously to reduce costs of regulation, why aren't those same forces more visible in producing pleasant cost surprises among public investments?

Unlike the case of public investments, no analytical models have been developed to explain *ex ante* cost estimation by regulatory bodies.[3] There is, however, a less formal literature that analyzes the procedures used in agency rulemaking and points out problem areas that can lead to over- or underestimates. Thus, Higgins and Buc (1997) argue that inadequacies in EPA methods bias the cost estimate towards a cost overestimate. In particular, they assert that in addition to the failure to consider innovation or cost-reductions through learning by doing, EPA analyses generally fail to acknowledge the overhead or

[3] However, there have been efforts to develop models to explain cost estimates by regulated firms. For example Kwerel (1977) has argued that under an effluent fee policy firms have an incentive to underestimate compliance costs, while under a marketable permit policy the incentive is reversed. He then shows that a hybrid instrument, combining effluent fees and marketable permits, can be designed that gives the proper incentives to firms. Spulber (1988) has extended this work to allow for joint effects of regulation in the product markets. Although strategic behavior by firms is generally thought to produce overestimates of the cost of regulation, under some circumstances regulation might be advantageous to at least some firms in the industry, in which case strategic behavior would very like call for a cost *under*estimate. Some writers have suggested that firms have sought regulation to "raise rivals' costs" (Salop and Scheffman, 1983). Perhaps an example is provided by du Pont's seemingly enlightened response to CFC regulation. Since it owned patents on a number of promising substitutes, the company may have viewed the CFC phaseout as an opportunity to increase market share (Morrisette, 1989). Yet, Hammitt (1997) still found that costs were still overestimated, at least in the early phases of regulatory development.

"fixed" nature of certain costs, treating them as marginal to the environmental regulation when they probably are not.

Fraas and Lutter (1996) also find fault with the cost estimates produced by the EPA. However, they believe that costs are more likely to be underestimated because of errors of omission during the rulemaking process. In three of the five RCRA rules examined by the authors, the EPA failed to include the costs of an important waste stream consisting of "nonhazardous" toxic wastes, such as batteries and fluorescent lamps. These wastes were excluded from the cost estimate because of uncertainty whether they would be subject to the rule, as well as a lack of data at the time of the analysis was conducted. However, the rules were later judged to apply to these wastes. A subsequent rule exempted these wastes at an estimated savings of $200 million, an amount the authors infer to be a cost that should have been in the original rule.

The other strand of literature that is of interest consists of a handful of papers, like the present one, that attempt to compile broad-based assessments of the accuracy of environmental or occupational regulations affecting the private sector. The earliest study we are aware of was conducted by the consulting firm Putnam, Hayes and Bartlett (PHB, 1980), which compared sector-level capital expenditures for pollution control to those originally forecast by EPA. Part of the study also looked at the accuracy of industry forecasts. PHB found that EPA tended to overestimate capital costs more often than they underestimated them, with forecasts ranging from 26 percent below to 156 percent above reported expenditures. For industry the overestimates were somewhat larger. Unfortunately, the reliance on aggregate data raises many issues about the interpretation of the results.[4]

The Office of Technology Assessment (OTA, 1995) conducted a wide-ranging review of the methods OSHA uses to examine hazard control options and estimate regulatory impacts. Included in their review are six independent studies containing *ex ante/ex post* cost comparisons, all of which are included in the present study (see Table 2). OTA found that most attention is placed on so-called "conventional" control measures rather than on new technology. They argue that "such bias is not surprising, given the 'feasibility demonstration' orientation of the agency's rulemaking logic and the need for control technology assumptions capable of standing up well under 'substantial evidence' scrutiny by the courts later. But this narrowed focus leaves a significant gap in the vision of the potentially available control options that OSHA can bring to the policymaking debate." Overall, the OTA report concluded that "the actual compliance response that was observed included advanced or innovative control measures that had not been emphasized in the rulemaking analyses, and the actual cost burden proved to be considerably less than what OSHA had estimated" (page 10).

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[4] The PHB (1980) study is based, in part, on the Pollution Abatement Cost and Expenditure Survey (PACE) collected by the Bureau of the Census (1972-1995). Although the PACE data are neither regulation-specific nor disaggregated beyond the environmental receiving medium, PHB argued that they were suitable for at least rough *ex ante/ex post* comparisons of the early period of environmental regulation. However, this is highly debatable.

A recent study by Goodstein and Hodges (1997) of a dozen EPA and OSHA regulations finds that most pollution control programs turn out to be less costly than had been estimated beforehand. They find that "reducing pollution emissions at the source. . . is almost certain to be (substantially) cheaper than we think it will be." They conclude that the overestimates result from new technologies that are developed in response to the regulations: "when industry is required to lower pollution output, it usually doesn't just slap a new filter on an existing process; it often invents new technology." Our approach differs from that of Goodstein and Hodges in several ways. First, as Squitieri (1997) has noted, Goodstein and Hodges do not grapple with key baseline issues which can affect the quantity of emission reductions actually induced by the regulation. Second, their conclusions rest, in part, on comparisons with *ex ante* studies conducted by industry. Since strategic behavior on the part of industry may lead them to overstate costs, the present study focuses exclusively on *ex ante* cost estimates developed by the regulatory agencies. Third, Goodstein and Hodges include in their list not only comparisons of *ex ante* and *ex post* costs, but also comparisons of an *ex ante* estimate with a later *ex ante* estimate. We limit ourselves to the former.

## III. DEFINING REGULATORY COST ESTIMATES

Although the notion of "regulatory cost estimation" may appear straightforward, in actuality it is anything but. The hard part is to identify just what it is that ought to be compared. After all, comparing costs *ex ante* and *ex post* means more than just determining what is spent; care is also required to ensure comparability in what is being purchased. To shed light on the conceptual issues we begin by asking what do we mean by "cost"? What do we mean by "regulation"? And what do we mean by "estimates"?

*Cost*. To determine the cost (or benefits) of a regulation, one must compare conditions in a world with the regulation to conditions in a world without it. To produce *ex ante* estimates, both the "with" and the "without" scenarios must be modeled; they cannot be observed. For the *ex post* calculation, the world with the regulation is observed, but the counterfactual is not. To produce an *ex post* estimate, one must determine the actual outcome empirically, and compare it to a hypothetical baseline based on the *status quo ante*. The construction of baselines is one of the most difficult and contentious parts of regulatory cost analysis. In other words, regulatory cost estimates can hardly escape being to some degree hypothetical whether they are made *ex post* or *ex ante*. The definition of baselines is therefore in some degree arbitrary, depending as it does on the analysts' beliefs on what would have happened without the regulation.

To an economist, the cost of a good or service is the maximum value of the opportunities foregone in obtaining that good or service.[5] Table 1 reproduces with minor alterations a taxonomy of the costs of environmental regulation developed by Jaffe et al. (1995) moving from the most to the least obvious. We have added a column to the right, indicating whether

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[5] More precisely, the cost of a regulation is equal to "the change in consumer and producer surpluses associated with the regulation and with any price and/or income changes that may result" (Cropper and Oates, 1992, p. 721).

costs in each category are typically part of *ex ante* estimates developed by regulatory agencies. The list is topped by the capital and operating expenditures associated with regulatory compliance. Such activities are typically carried out and paid for by the private sector, although some activities fall on state and local governments (e.g., drinking water) and some on the federal government (e.g. compliance expenditures of TVA and Bonneville Power Administration). As shown, such capital and operating costs are routinely considered in regulatory cost analyses.

**Table 1: A Taxonomy of Costs of Environmental Regulation**

| Cost category | Counted in RIA? |
|---|---|
| DIRECT COSTS | |
| Private Sector Compliance Expenditures | |
| Capital | Yes |
| Operating and maintenance | Yes |
| Public Sector Compliance Expenditures | |
| Capital | Yes |
| Operating and maintenance | Yes |
| Government Administration of Environmental Statutes and Regulations | |
| Monitoring | Rarely |
| Enforcement | Rarely |
| Other Direct Costs (including negative costs) | |
| Legal and Other Transactional | Sometimes |
| Shifted Management Focus | No |
| Disrupted Production | No |
| Waiting time | Sometimes |
| Intermedia pollutant effects | Sometimes |
| Other natural resource effects | Sometimes |
| Changes in maintenance requirements of other equipment | Sometimes |
| Worker Health | Sometimes |
| Stimulation of innovation in clean technologies | No |
| INDIRECT COSTS | |
| General Equilibrium Effects | |
| Product Substitution | No |
| Discouraged Investment | No |
| Retarded Innovation | No |
| Transition Costs | |
| Unemployment | Sometimes |
| Plant closures | Sometimes |

*Source*: Adapted from Jaffe et al. (1995).

A few other cost categories are occasionally addressed in the *ex ante* analyses. Some of these categories are shown under "other direct costs." They are particularly noticeable in analyses of automobile regulations, and they often show up as negative costs. Thus, an important element in the estimates of the cost of standards for new motor vehicles is the improved fuel economy and reduced maintenance requirements attributable to the introduction of computerized fuel injection, a technology that provides many engine benefits besides lower emissions (USEPA, 1993). The cost analysis for the vehicle inspection and maintenance (I/M) program also claims large fuel economy benefits resulting from better engine performance (USEPA, 1992). In a similar vein, the Regulatory Impact Assessment (RIA) for the regulation to limit lead in drinking water credits the regulation with reducing mineral deposits in pipes, thereby lowering maintenance expenses. Not all the "other" costs counted in RIAs are negative. For example, the I/M cost analysis counts the cost of motorists waiting in queues at testing stations. Also, adverse effects of regulation on workers have occasionally appeared in RIAs. Similarly, some pesticide regulations have led to substitution of compounds that are more acutely toxic but less environmentally persistent than those they replaced.

In contrast, the other categories in the cost taxonomy, including government administration of environmental statutes and regulations, some of the other direct costs, general equilibrium effects, and transition costs are not generally considered in regulatory cost estimates. For one thing, often it only makes sense to speak of these costs with respect to regulation in the aggregate rather than for specific regulations. The cost of administration of environmental statutes is usually omitted because of a joint cost allocation problem; besides, the government's costs are thought to be small relative to those of the private sector. As for the other costs, the principal reason they are excluded is the lack of credible information or insufficient analytical resources to apply whatever data or models do exist. Thus, additional management resources or disrupted production is plausibly important, but no *ex ante* estimates have been prepared.[6]

The general equilibrium effects of environmental regulation are likely to be important, but are likewise virtually impossible to examine empirically. Computable general equilibrium (CGE) models have not been tested against real-world outcomes, and may be untestable. Builders of these models content themselves with observing that the input parameters are reasonable and based on empirical data. Regardless, for most individual regulations focused

[6] There have been some attempts to measure these costs *ex post*, at least indirectly, such as Gray and Shadbegian (1993) and Joshi et al. (1997) in the steel industry, and most recently, Morgenstern et al. (1998a) for a set of 11 industries. These studies estimate cost functions to examine the effect of reported abatement expenditures (as measured by PACE) on total cost. The other direct costs are positive if and only if the coefficient on the pollutant abatement expenditure variable is positive. While the Joshi et al. (1997) study finds multipliers up to 12, Morgenstern et al. (1998) estimated the multiplier to be 0.8, suggesting that the other direct costs are more than offset by savings elsewhere in the production process. This may indicate the joint cost aspect of some environmental spending. Of course, this analysis can only be done for fairly large aggregates of regulations, for that is the only way the *ex post* compliance expenditure data are reported.

on a single sector--and thus not involving many spillover impacts from one sector to another--one can say on *a priori* grounds that general equilibrium effects are likely to be *de minimis*.[7]

In the 1970s and '80s the effects of some EPA regulations on plant closures and unemployment were estimated, albeit crudely, as a part of the economic analysis--e.g., Effluent Guidelines for industrial water pollutant discharges. In recent years, this style of economic analysis has been generally superseded by more sophisticated analyses of the welfare effects of regulations. The Unfunded Mandates Reform Act of 1995 requires that cost estimates take into account transitional and indirect costs. The cost analyses that we examine were conducted prior to the growing interest in indirect cost, and thus do not generally include these cost categories.[8]

*Regulation*. The issue here is one of scale. There may be good reasons why one would want to estimate (i) the cost of meeting an emission regulation at a particular plant, (ii) the cost of an emission regulation for the entire country, or (iii) the cost of meeting an ambient environmental quality objective. As the scale increases, the uncertainties multiply, and biases of estimation that were not evident at low levels of aggregation may become important.

Our focus is on the cost estimates prepared by regulatory agencies for specific rules. Since for every major rule (those with estimated annual costs in excess of $100 million) agencies must prepare, under executive order, an RIA, also known as an "Economic Analysis," containing an estimate of compliance costs of the alternatives considered, we believe it is possible to make some judgments about the qualities of those estimates and give at least a preliminary answer to the question of whether systematic biases exist.

*Estimates*. In evaluating the quality and usefulness of a regulatory cost estimate, it is important to keep in mind who is making the estimate and what its purpose is. Before a regulation is adopted, information about response options and costs may be asymmetrically distributed; potentially regulated parties generally have better information about alternatives for meeting requirements than regulatory agencies and advocacy groups. At the same time, however, industry cost estimates may be too high if firms do not fully anticipate cost-saving measures they may discover once resources are directed to the task of compliance.[9]

The above-cited characteristics are clearly important for cost comparisons. Even more important, however, is the fact that credible *ex ante/ex post* comparisons cannot be made if the relevant studies don't include the same components or don't refer to the same cost concepts. For example, there are wide divergences in the *ex post* cost estimates of the low emission

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[7] A recent paper by Garber and Hammitt (1998) suggests that the public valuation of a firm's stock may be reduced by the uncertainty associated with pollution liability, e.g. Superfund.

[8] In any event, the number of plant closures or jobs lost as a result of environmental regulation is likely quite small. See Morgenstern et al. (1998b).

[9] The hypothesis that environmental regulation triggers innovation that can offset some or all environmental compliance costs was initially proposed by Porter (1991) and supported by Porter and van der Linde (1995). For a counter view see Jaffe et al. (1995) and Palmer et al. (1995).

vehicle (LEV) standard reported by Cackette (1998) and by Energy and Environmental Analysis (1998), with the main difference revolving around the treatment of indirect costs. There is a similar difference between two *ex ante* studies conducted by the California Air Resources Board (CARB) and Sierra Research (1994). For our purposes it is far more important to match up studies with the same components than to answer the question of whether the indirect costs belong in the estimate.[10]

Part of the difficulty of making cost comparisons is that actual outcomes can deviate from predicted ones in so many ways that it is not easy to know what is comparable. Consider the following example. Suppose a cost estimate for a pollution abatement regulation is to be prepared, based on an industry of 100 plants, with pre-regulatory emissions averaging 100 units per day. Suppose further that the regulation calls for emissions to be reduced to 25 units per day at a per-plant cost of $200,000 per plant. After implementation an industry trade association does a survey to estimate the real cost of the regulation. To simplify the discussion we assume the baseline is identical to the *ex ante* estimate. Some of the possible outcomes are shown in Table 2.[11]

**Table 2. Cost estimation: Some hypothetical cases**

| | *Ex ante* | Alternative *ex post* outcomes | | | | |
|---|---|---|---|---|---|---|
| | Estimate | 1 | 2 | 3 | 4 | 5 |
| Number of plants | 100 | 100 | 150 | 100 | 100 | 200 |
| Emissions, pre-reg. | 100 | 100 | 100 | 50 | 100 | 50 |
| Emissions, post-reg. | 25 | 25 | 25 | 25 | 50 | 25 |
| Cost per plant | $200k | $100k | $200k | $200k | $200 | $100k |
| Aggregate cost | $20M | $10M | $30M | $20M | $20M | $20M |
| Emission reductions | 7500 | 7500 | 11250 | 2500 | 5000 | 5000 |
| Cost per emission unit | $2666 | $1333 | $2666 | $8000 | $4000 | $4000 |

The first of these five cases is an example of mis-estimation of per-plant costs. The next three are examples of various ways in which the "quantity"--i.e. emission reductions--of regulatory output is different from prediction.

Case 1. The cost per plant is overestimated by a factor of 2, while all other quantities are estimated correctly, so that costs per emission unit as well as costs per plant are overestimated. We believe this is the situation that most observers have in mind when they assert that costs are overestimated.

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[10] Smith et al. (1998) contains an interesting discussion of how long-run and short-run costs as well as marginal and average costs are frequently confused in cost comparisons of the federal SO2 program.

[11] Similar examples can be developed for other types of regulation, although they may not be so easily quantified. For private land use regulation, for example, the three "quantity" elements of interest are the land area involved and the range of permitted activities before and after regulation. The cost of regulation is the reduction in the market value of the land that would accompany implementation of the regulation.

Case 2. In this case, costs are estimated correctly on a per-plant basis, but an underestimate of the number of plants means that the total costs exceed the estimate. This type of uncertainty would include the case where the total number of plants was known but the number of plants with a given characteristic or technology is not. This might apply, for example, to landfill sites subject to corrective action requirements.

Case 3. Again, costs per plant are estimated accurately, but the pre-regulatory emissions are much less than originally thought. This could be considered a case of accurate estimation, because the costs per plant are estimated accurately and the environmental goal is met. Alternatively, it could be considered underestimation because the cost-effectiveness, measured by the cost per unit emission reduction, is underestimated.

Case 4. Here again costs per plant are estimated accurately, but the post-regulatory emissions are not. Ordinarily, this will not happen with command and control (CAC) regulation because the post-regulation emissions are usually set by the regulation. However, it could occur, for example, if the regulation is not enforced successfully or if it calls for the installation of a specific technology, rather than the achievement of an emission target.

Case 5. In this case estimation errors are made in the number of plants, the pre-regulatory emissions and the cost per plant. Depending on one's evaluation criterion it is possible to say that costs are overestimated (cost per plant), underestimated (cost per unit), or predicted accurately (aggregate cost).

*A word about economic incentives.* The foregoing discussion was written primarily with traditional CAC regulation in mind. Increasingly, though, modern environmental regulation makes use of economic incentive (EI) approaches and, in fact, these are heavily represented in our sample. *Ex ante* estimation of outcomes is just as important for economic incentives, but there are some differences in the uncertainties encountered. Although economic incentives can take a myriad of forms, we consider here only the pure quantity and price instruments, i.e. marketable emission permits and emission fees.

In an marketable emission permit system, what is specified beforehand is the aggregate emission reduction; plant-specific emission reductions are uncertain.[12] The costs are uncertain *ex ante*, both at the margin and in total, and market simulation models are used to estimate *ex ante* costs. *Ex post*, we observe a market-clearing permit price, which we take, with some qualifications, as the marginal cost of abatement.

For an emission fee, the marginal cost--that is, the plant-level abatement cost--is specified *ex ante*, and so there is very little uncertainty about what the marginal cost will be. The uncertainty is in the slope of the marginal abatement cost curve, or alternatively, the demand curve for waste disposal services. Thus the *ex ante* estimate that is of most interest is the quantity of emission reductions. If demand is more responsive than predicted, then a given fee will result in more emission reductions than expected. The total cost under this

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[12] This is in direct contrast to the typical CAC regulation, where one fixes beforehand the emission reductions required from each plant, but the total emission reductions and the marginal cost of the regulation may not be known with certainty.

assumption will be greater or less than expected, depending on one's assumptions about the shape of the demand curve. For example, assuming linear demand, total cost will be greater than anticipated and average cost will be as expected. Despite the higher total cost, most observers would regard this case as a pleasant surprise, for the higher total cost is more than offset by the larger-than-expected emission reductions.

## IV. RESULTS

A combination of literature review and discussions with more than 50 environmental experts were used to develop as large a sample of rules as possible for this study. The basic criteria for inclusion in the study were the existence of (a) an *ex ante* cost estimate developed by a regulatory agency with substantial expertise in cost analysis, and (b) a relatively detailed *ex post* estimate, typically (but not always) prepared by an academic or independent analyst. At the state level we were only able to identify four rules, all from California, that met these criteria. Internationally, only three rules were included in our dataset. It is interesting to note that a number of the experts we consulted initially thought detailed evidence existed to substantiate claims of cost overestimates or underestimates for particular rules. However, upon further investigation, we were unable to locate detailed *ex post* information for several of the rules recommended by the experts. In the end, 25 rules were selected for inclusion in the study.[13] We believe our list is reasonably comprehensive at least as far as federal health and safety regulations in the U.S. are concerned. We are less confident regarding state regulations and not confident at all regarding regulations from other countries. It is certainly possible that other rules would qualify for inclusion in our dataset. We welcome nominations from our readers.

Problems of comparability among the different studies prevented us from performing a strictly quantitative analysis of the *ex ante/ex post* comparisons. Accordingly, we have developed a qualitative approach. We label an *ex ante* analysis as "accurate" if the *ex post* estimated costs fall within the error bounds of the *ex ante* analysis of if they are between 25 percent higher and 25 percent lower than an *ex ante* point estimate. If a regulation resulted in lower than expected costs because of low compliance rates, we classify it as an example of total cost overestimation. Of course, such cases are also examples of benefits overestimation.

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[13] SO2 Phase I and Phase II are actually part of the same regulation. However, because of large differences in the number of facilities covered and the stringency of the emission requirements, we treat them as separate rules. One reviewer pointed us to the National Highway Transportation Safety Administration's center-high-mounted stomp lamp rule. Actual costs for this rule were approximately double those forecast in the RIA. We have omitted it here because we focus on environmental and occupational health and safety regulations. We also omitted a number of smaller pesticide rules for which ex post studies are now in preparation because of their small economic impact.

In the case of CFCs, the initial RIA was significantly revised at the time the domestic rulemaking was finalized. However, since the initial RIA was most influential in the U.S. decision to sign the governing international accord (the Montreal Protocol) we treat it as the relevant *ex ante* analysis. Interestingly, the earlier (1986) analysis generally overestimated costs while the revised analysis (1988) was more accurate. See the appendices. For further discussion see (Hammitt, 1997).

Three outcomes are compared: the quantity of emission reductions achieved, unit pollution reduction costs, and total costs. The quantity of emission reductions achieved reflects the net effect of the quantity-related factors discussed in the preceding section, i.e., the number of firms or agents subject to regulation and the estimated emission rates with and without regulation. Overestimation of emission reductions implies that the regulators achieved smaller reductions than expected. This may arise because the reductions needed to meet compliance were smaller than initially estimated. Alternatively, the rule could suffer from low compliance rates or from technical deficiencies (e.g. poor performance of technology standards).

Unit pollution reduction cost outcomes generally refer to costs per unit of emissions reduced (over the relevant range), although other margins can be important in individual cases. In pesticide regulation, for example, the relevant margin is costs per acre. For the inspection and maintenance (I/M) rule, costs can be usefully expressed both as costs per unit of emissions or costs per vehicle.

Some of the studies cited did not make final judgments on whether costs were over- or underestimated, and they usually did not decompose those judgments into the three outcomes we examine here. We found that in more than half the cases the same conclusion was reached on both measures of cost, but there were some important divergences--enough, we hope, to make our taxonomy of more than academic interest.

Table 3 summarizes the results for the individual rules. A complete rule-by-rule analysis is contained in Appendix A. As shown, for each rule we provide the date the *ex ante* estimate was made, together with a citation of the *ex post* study.

**Table 3: Case Study Results**

| | Accurate | Overestimate | Underestimate | Unable to Determine |
|---|---|---|---|---|
| Quantity Reduction | 10 | 9 | 4 | 2 |
| Unit Pollution Reduction Cost | 7 | 12 | 6 | |
| Total Cost | 5 | 12 | 2 | 6 |

Pollution reductions were overestimated in nine of the *ex ante* analyses examined and underestimated in four of them. In ten cases, the quantity predictions were judged to be about right. The per unit costs of regulations were even more likely to be overestimated; in twelve cases per unit costs were overestimated, while they were underestimated in six cases. Total costs were overestimated for twelve rules and underestimated in just two cases and both were comparatively small regulations--EPA's aldicarb ban and OSHA's powered platform regulation.

Interestingly, these results vary somewhat by agency. Neither EPA nor OSHA evidenced a systematic bias in their *ex ante* estimates of the per unit costs of regulations.

EPA overestimated per unit costs for three regulations, underestimated them for four regulations and accurately estimated them for four. Of the four EPA regulations that had per unit cost overestimates, three were relatively small rules--coke ovens, dinoseb and aldicarb. OSHA overestimated per unit costs for three rules, underestimated them for two and accurately predicted them for three. In contrast, state and foreign agencies were far more likely to overestimate per unit costs than OSHA or EPA, doing so in six of the seven cases we examined.

Both EPA and OSHA tended to overestimate rather than underestimate quantity reductions. EPA overestimated quantities in four of the ten regulations examined and underestimated them in one. The tendency was even more pronounced for OSHA; the agency overestimated reductions in five of eight cases and underestimated then in none. One of the California rules had an underestimate of quantity reduction, one was accurate, and we were unable to make a judgment for two others. Two of the international regulations, both congestion fees, underestimated quantity reductions. The category was irrelevant for the third international regulation.

The effect of the quantity mis-estimation appears to be important. Both EPA and OSHA had a tendency to overestimate the total costs, even though they did not tend to overestimate per unit costs. In a number of cases, total costs were lower than expected because the rules did not produce the anticipated compliance levels. Although these are examples of an overestimation of total cost, they are also examples of benefit overestimation and the result does not imply that the regulation *as envisioned* was less expensive than predicted.

An often discussed issue is whether the accuracy of cost estimates is improving over time. For the five federal rules enacted prior to the expansion of Executive Office oversight of federal rulemaking in1981, two had overestimates of marginal cost, two had underestimates, and the other was accurate. For the thirteen post-1981 rules, four had overestimates, four had underestimates and five were accurate. Thus overall accuracy does not seem to be improving over time.

In contrast, there does appear to be some improvement in the accuracy of pollution reduction forecasts over time. For the pre-1981 rules, four of five overestimated pollution reduction; after 1981, five *ex ante* analyses overestimated quantities, one underestimated them, while seven were accurate. The improvement in quantity forecasting is reflected in the total cost estimates. All five pre-1981 *ex ante* analyses overestimated total costs. The post-1981 estimates overestimated total costs in five cases, underestimated them in two, and were accurate in four cases. While overestimates are still more likely than underestimates, a much larger share of both total cost and quantity predictions have been accurate for recent rules.

One striking point that emerges from our dataset is the relatively large representation of rules incorporating market-based incentives, which account for only a tiny fraction of total regulatory activity in the U.S. and elsewhere. By our count eight such rules (mostly larger ones) are included in the data.[14] For seven of these eight rules the agencies overestimated costs, in some cases substantially. For the eighth rule, which reduced the amount of lead permitted in gasoline, costs may also have been overestimated, but the data are inadequate to make a clear case (Nichols, 1997). Thus, although the sample is small, it appears that rules that use an economic incentive approach are more likely to result in cheaper-than-expected pollution reductions.

As to why these market-based rules are so heavily represented in our dataset. Two obvious answers strike us: (1) it is easier to obtain *ex post* information on rules involving market-based incentives; and (2) economists, who conduct most of the *ex post* studies, have a proprietary interest in the performance of economic incentives, much as a parent has a proprietary interest in his child's school performance. While we do not suggest this leads to a bias in their assessments, it may create a greater interest in conducting the *ex post* studies in the first place.

## V. DISCUSSION

Our examination of the case study results and the extant literature, together with discussions with knowledgeable and experienced regulatory warriors at regulatory agencies and elsewhere, generated numerous explanations of why *ex ante* cost estimates by regulatory agencies might be systematically different from *ex post* calculations. Perhaps we should begin, however, by dismissing a hypothesis that appears to be refuted by the preponderance of the evidence, namely, that regulatory agencies may "understate costs . . . because . . . their self-interest lies in regulation," (OMB, 1998; for a similar argument, see Hahn, 1996). We take no position on whether bureaucrats engage in agency-aggrandizing behavior, but at OSHA and the EPA, at least, our data does not support the notion f systematic underestimation of regulatory costs.

We have grouped the remaining explanations into five categories. The first is technological innovation, considered by Goodstein and Hodges and others to be the primary explanation for overestimation of costs. But it is not the only possible explanation, and we follow it with four others that seem to be important in at least some rules. These include "quantity errors," including both baseline and compliance issues, plus three explanations associated with the procedural and methodological practices in rulemaking. These hypotheses are not mutually exclusive; each can be true for different rules, and in some cases may each apply to the same rule.

### 1. Technological Innovation

Under most circumstances regulatory cost estimates ignore the possibility of technological progress. As noted, regulators often have an obligation to identify a means for firms to meet the regulation, a requirement that seemingly precludes the projection or

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[14] Leaded gas, CFCs, SO2 Phase I, SO2 Phase 2,, RECLAIM (NOx), RECLAIM (SOx), Singapore auto licensing, and the Bergen toll ring.

extrapolation of future costs or the expectation of cost declines. Technical change is, after all, notoriously difficult to predict; all we can say with some confidence, based on historical experience, is that the cost of compliance will decline, but we cannot say at what rate.

In the case of SO2, scrubbing turned out to be more efficient and more reliable than expected. *Ex ante* estimates assumed SO2 removal efficiencies of about 80-85 percent whereas typical performance has come in at around 95 percent. Similarly, *ex ante* reliability was assumed to be around 85 percent. In fact, scrubbers have typically run in excess of 95 percent of the time. Unanticipated opportunities have also arisen to use low sulfur coal in older boilers. Experiments and minor modifications at some plants revealed that low sulfur coal could be blended with high sulfur coal up to a 40/60 mixture, compared to the 5/95 mixture originally estimated. Analysts have argued that these unanticipated innovations were driven by competition from rail, some of which was driven by unanticipated innovation in that industry, as well as by market opportunities, enhanced by the SO2 trading scheme which allowed firms to profit from marginal reductions in emissions (Carlson et al., 1998; Smith et al., 1998).

The case of CFC phase-out provides another example where unanticipated innovation led to lower costs. When the original cost analysis was performed it was not anticipated that HFC-134a could be substituted for CFC-12 in refrigeration. However, as Hammitt (1997) notes, "since 1991 most new U.S. automobile air conditioners have contained HFC134a (a compound for which no commercial production technology was available in 1986) instead of CFC-12" (page 13). He cites a similar story for HCFC 141b and 142b, which are currently substituting for CFC-11 in important foam-blowing applications. In contrast, Hammitt notes that "reductions in CFC-113 consumption have not relied as extensively on new compounds; major reductions have been achieved by substituting other solvents and blends and by altering production processes so that smaller quantities of solvent are required" (page 13).

In its review of OSHA standards, OTA (1995) cites a number of cases of low-cost innovations not anticipated in the Agency's *ex ante* analysis. For example, for vinyl chloride "a significant production improvement not foreseen . . . was the proprietary "stripping" process commercialized within a year of promulgation, which provided a substantially improved means for producing PVC resin while reducing vinyl chloride exposures" (page 57). For cotton dust, the OSHA analysis ". . . missed the sizeable extent to which dust control was achieved as a by-product of an aggressive drive to modernize" (page 57). However, OTA also cites the case of occupational lead exposures where the anticipated technologies have *not* materialized. In that industry the emphasis has been on respiratory protection programs, rather than on the expected engineering controls. "Furthermore," OTA notes, "the 'new technologies' envisaged at the time of rulemaking for compliance in the blast furnace area of plants have not progressed; the single U.S. smelter using the Bergsoe process went bankrupt in the mid-1980s, and hydrometallurgy still remains 'on the horizon' " (page 57).

A corollary of the technical change issue concerns the effect of time delays on the costs of compliance. Consider the case where a regulation is proposed and the target industry protests, producing cost estimates suggesting that implementation would cause widespread bankruptcies, raise product prices, and put people out of work. The protests successfully cause the postponement of implementation of a regulation, and may work to reduce its stringency. Eventually, however, a regulation is promulgated, whereupon it is discovered that the cost of compliance is much less than originally predicted. Afterwards, the case is cited as yet another example of wolf sightings from industry. And yet, chances are that if the regulation had been promulgated immediately the costs would have been more nearly what was initially estimated. In his study of CFCs, Hammitt (1997) notes that during the two year period the rule was being developed "great attention was focused on the identification and development of technological alternatives to CFCs" (page 11).

Environmentalists and analysts such as Goodstein and Hodges with some justice see technological innovation as an important reason why costs are frequently overestimated.[15] Innovation takes time, and perhaps the delays caused in part by the original cost estimates were useful in allowing the industry time to find better and cheaper ways of meeting the regulation. Still, time is not always a decisive input; implementation of the I/M rule was much delayed beyond its original 1992 deadline, and the costs were still substantially underestimated. The fact that technological progress is often responsible for lower than expected costs does not necessarily imply that regulation "produces" technological innovation. The issue of "technological forcing" is separate from whether cost savings can be attributed to unanticipated innovation.

## 2. Quantity Errors: Baseline and Compliance Issues

A key determinant of overall cost is the amount of pollution reduction that results from a regulation. In many cases, prospective analyses have misestimated the emissions reductions resulting from a rule. As a result, total costs are different than expected, even though the per-unit cost was forecasted accurately. Frequently, regulations that have produced lower pollution reductions than were expected are cited as examples of *ex ante* cost overestimation. However, in these cases, total benefits are smaller as well. Society pays less, and it gets less.

An inaccurate prediction of reductions can occur in one of two ways. First, the *ex ante* analysis can misestimate the baseline emissions that would exist without the regulation. In the case of OSHA's 1972 asbestos rule, the *ex ante* overestimate of the total cost of the regulation is attributable to (erroneous) exposure assumptions (Mendeloff, 1988). Similarly, the *ex ante* analysis of OSHA's cotton dust rule significantly overestimated the number of workers that would be affected by the regulation (Viscusi, 1992). Analysts can also fail to foresee developments affecting the quantity of emissions that must be reduced to comply with a rule. Estimates of the costs of the sulfur dioxide provisions of the 1990 Clean Air Act failed

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[15] Sometimes technological innovation can be quite simple. The NAS (1975) reports that the decision to set a tolerance for hexachlorobenzene (HCB) was based on an estimate that at least 17,000 head of cattle would have to be destroyed if the tolerance was set at 0.5 ppm. However, after the 0.5 ppm tolerance was officially established farmers took various steps to modify the impact of the decision on their cattle, and only three cows had to be destroyed (see Dominick, 1974).

to foresee approximately two million tons of S02 reductions that would have occurred as a result of railroad deregulation and other factors unrelated to the EPA regulations (Burtraw, 1998a). Although in our dataset all the baseline problems involved overestimates, they could, in principle, include underestimates as well.

Besides misestimating baseline emissions, the *ex ante* analysis can inaccurately predict the regulation's effectiveness in achieving the desired pollution reduction. In the case of OSHA's 1976 coke oven standard, a retrospective analysis found that industry expenditures had been far below expectations, but this was mainly due to incomplete compliance (Mendeloff, 1988). Similarly, the ban on the pesticide dinoseb resulted in a *net savings* after the EPA granted an exemption allowing farmers to use paraquat on their crops. OSHA's occupational lead standard was met primarily through the use of protective gear for workers rather than the engineering approach envisioned by the *ex ante* cost analysis. Although workers were protected, air lead levels in plants remained extremely high several years after the regulation's promulgation (OTA, 1995). In these cases, looking only at total costs is misleading, because the high cost of the regulations resulted in compliance strategies that did not produce the desired benefits. Paradoxically, the underestimation of per-unit costs can lead to the overestimation of total costs.

Even when compliance with a regulation is as expected, the regulations may, nonetheless be ineffective in reducing pollution. The *ex ante* analysis of EPA's vehicle inspection and maintenance program slightly underestimated the costs of vehicle repairs but dramatically overestimated the effectiveness of the repairs in reducing vehicle emissions (Harrington et al., 1999).

### 3. Uncounted Cost Reductions Achieved During the Regulatory Review and Public Comment Periods

Under the Administrative Procedures Act (APA) agencies are required to go through a series of standard procedures including formal proposal, and public notice and comment, before new regulations can become effective. These procedures have become a bit of a ritual in Washington, often spawning complex technical, economic and legal arguments between agencies and the interested public. Not surprisingly, rules are often modified between the time they are proposed and the time they are published as final regulations in the *Federal Register*. What is less clear is whether the initial cost estimates are modified to fully reflect the rule changes.

The conventional wisdom is that agencies propose relative stringent rules with the tacit understanding that the final regulations will be softened somewhat in response to comments from prospective regulatees. Agency staff often justify such tactics as a means of pressuring an industry reluctant to reveal internal cost or emissions information that is necessary to set "reasonable" rules. One recent paper documented that cost-saving rule changes made during the regulatory development process occurred in all twelve of the rules studied (Morgenstern and Landy, 1997).

Sometimes changes come in response to concerns raised by OMB. Sometimes they occur simply as a result of data or analysis generated within the regulatory agency but not available at the time the rule was initially proposed. And sometimes the cost-reducing changes are made in response to industry–supplied data or as a result of industry lobbying. One study of EPA's rulemaking process for effluent guidelines between 1972 and 1978 showed a marked asymmetry in the number and the nature of comments on the rules (Magat et al., 1986). The affected industries generated most of the comments on the regulations, and virtually all the comments on their specific characteristics (costs predicted and emission reductions required). Environmental and public interest groups commented infrequently, and when they did their comments were of a general nature, having more to do with the pace with which regulations were being prepared, rather than the details of particular regulations. Between the initial contractor document and the proposed regulation, and again between the proposed and promulgated regulations, the effluent guidelines were loosened and cost estimates were raised.

Particularly for large, complex rules, changes often involve the exclusion of certain industrial or process subcategories, exclusion of specific waste streams, timing of implementation, and record keeping requirements. Some of these changes affect the quantity of emission reductions required, other affect the cost per unit of emission reduction. Examples of such changes can be found in the lead phasedown, CFC, and reformulated gasoline regulations.

The key question is whether the rule changes are always or even systematically captured in the final cost estimates issued by the agency. Especially since rule changes often occur at the very end of the process, sometimes just days before promulgation of the rule, in many cases without the input of agency's economic experts, our observation is that many of these changes are not captured in the final cost estimates. Although we are not aware of any formal study, the anecdotal evidence is fairly strong on this point. The failure to capture all the cost-saving changes means, almost by definition, that the agency's estimate will overstate the true costs of the rule.

## 4. Estimating Maxima Rather Than Means

There is a tendency, sometimes inadvertent and sometimes deliberate, for a regulatory cost analysis to produce an estimate of the maximum cost, rather than the mean. Inadvertent estimation of the maximum cost may result from the agency's use of out-of-date information on installed pollution control equipment. If, for example, the agency data does not record the most recent efforts to reduce emissions, the quantity of emissions required to meet a particular goal might be overestimated.

Inadvertent estimation of the maximum cost may result from the agency's reliance on the regulated industry for data. The industry is the source, directly or indirectly, of most of the data used to support cost estimates as well as the possible improvements in firm performance that might be called forth by new regulation. Sometimes, as in the recently-concluded multi-media rulemaking for the pulp and paper industry, the EPA seeks the cooperation of the main trade association--in this case the American Forest and Paper Association--which may, in turn, solicit cost data from its members or serve as a conduit for an Agency-designed questionnaire. In addition, it is noteworthy that EPA cost studies are frequently done by outside contractors, who hire industry experts (often ex-employees of the industry) to make estimates. If the agency relies on cost and compliance information from the industry, then agency cost estimates might be subject to the same biases as industry estimates.

The industry also has opportunities during the regulatory process to produce cost estimates even when unsought by the regulators. For example, trade associations sometimes hire contractors to conduct their own cost studies, as when the auto industry retained Sierra Research to estimate the cost of meeting the LEV and ULEV standards.[16] Regulators may harbor skepticism of these estimates, but they still must be addressed in the rulemaking process and some explanation given for major disparities in estimates. The mere existence of such studies may exert upward pressure on regulators' cost estimates.

While the industry may be motivated by strategic considerations, overestimates of costs may also result from firms' unwillingness to devote resources to figuring out the best way to comply with a proposal that may or may not be the final rule. Asked "what will it cost?" a firm's analyst may respond with the cost of an "off-the-shelf" compliance technology. Further study may reveal that compliance cost can be cut substantially through clever engineering that takes advantage of particular characteristics of the production technology. In this case firms are not employing strategic behavior, but just choosing not to expend resources in advance of a final regulation in determining how compliance could be achieved at minimum cost. This approach might also be desired by the firm for reasons of prudence.

There may also be occasions when the regulator will quite deliberately estimate a maximum cost, for example, if the costs of compliance are thought to be modest, if underestimation of costs risks embarrassment, or if court challenge seems likely. It is standard practice in EPA's Effluent Guidelines Division, for example, to attempt to provide an upper bound for a compliance cost estimate.[17] Even if the applicable statute only permits economic factors to enter in an indirect manner, underestimation may jeopardize the legal standing of the rule.[18]

In addition, a good deal of health and safety regulation is "technology-based," which means that the regulator identifies an emission-reducing technology and then writes the regulation so that the identified technology can meet it. The language used in industrial pollution control statutes makes clear the importance of feasibility: "Best Practicable Technology," "Best Available Technology Economically Achievable," "Best Conventional Technology" (Clean Water Act); "Best Available Control Technology," "Lowest Achievable

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[16] For pesticides, EPA's analysts often contact a sample of county extension agents to estimate the acreage of crops planted in an affected crop plus the availability and effectiveness of alternative pesticides.

[17] Personal communication, William Anderson and William Wheeler, Effluent Guidelines Division, June 30, 1998.

[18] See Downing (1995) for a discussion of how economic factors enter into different environmental laws.

Emission Rate" (Clean Air Act). Note the emphasis on technology that is available and achievable, words that impose a responsibility on the Agency to identify a technology in use that can meet the standard the Agency wishes to impose. The cost estimate is, of course, based on the designated technology. Regulated firms are free to meet the standard by any method, and they will use the identified technology only if its costs are lowest of the alternatives. Thus the agency is once again estimating a maximum cost.

### 5. Asymmetric Correction of Errors of Estimation

Estimation of costs is full of uncertainties in the best of circumstances, and it is understandable that such estimates would be subject to large errors. These errors come not only from an understandable failure to anticipate technological change, but from equally understandable errors in characterizing the universe of firms or agents likely to be affected by the regulation, as well as the cost and effectiveness of the compliance technologies employed. This is true even if the agency analysis is free of the errors noted above. In the absence of bias, of course, we would expect costs to be underestimated as often as it is overestimated. We have already discussed how internal and external pressures as well as new information can cause the regulation itself to change after the cost estimate is prepared. The cost estimate itself can also be changed if errors are pointed out

However, gross underestimates of costs are more likely to be brought to the regulator's attention by worried members of the regulated community. The communication of such concerns to regulators can cause a change to the regulation or the cost estimates, causing low-ball cost estimates tend to be eliminated or transformed into something more "reasonable." No corresponding pressures can be found for gross overestimates, which causes an apparent upward bias in regulatory cost estimates. It is quite likely, for example, that the error in the analysis of OSHA's formaldehyde regulation, which resulted in a cost overestimate, would have been corrected if it had led to an underestimate of costs.

## VI. CONCLUSIONS

The debate over whether the costs of environmental regulatory programs are under- or over-estimated is really two debates, and it is important not to confuse them. One issue is whether all the cost elements are being included in the estimates. Many observers argue that important cost elements are being left out, and if they were included they might swamp the costs that are now included. These omissions include the diverted management attention and the innovations that weren't made because of the time and resources devoted to complying with environmental regulations. These omissions also include the general equilibrium effects, the adjustments that ripple through the economy when resources are diverted from one use to another. Not only are such cost elements difficult to measure, they are also virtually impossible to attach to individual regulations. Thus it is no surprise to find that those who argue that important costs are ignored in regulatory decision-making tend also to be those who point to the costs of environmental regulation in general, rather than to the costs of individual regulation.

The second issue is the one we have concentrated on in this paper: whether the cost elements that are estimated during regulatory procedures contain systematic errors, and if so, what the implications are for regulatory policy. Unlike the first issue described above, this issue is amenable to empirical test. To resolve it, some experts call for more intensive scrutiny of the procedures used by regulatory agencies to collect information, choose rulemaking alternatives, and evaluate costs. Hahn (1996), for example, argues that "without a detailed evaluation of each regulatory analysis and Federal Register preamble, it is difficult to say how individual analyses are likely to be biased" (page 224). Close analysis of rulemaking procedures and the documents produced to support them is certainly important and useful work.

Close study of individual rulemaking analyses, however, is not sufficient to determine whether RIAs accurately predict the realized direct costs of regulations. What is needed in addition is a systematic comparison of *ex ante* cost estimates generated by RIAs to the *ex post* assessments of the same rules. That is what we attempt to provide in this paper. Our review of over two dozen *ex ante/ex post* comparisons indicates that *ex ante* estimates of total cost have tended to exceed actuals. We find this to be true of 12 of the 25 rules in our data set, while for only 6 were the *ex ante* estimates too low. Since the overestimates occur more frequently in the larger rules, the dollar-weighted predominance of overestimates would be even higher. For federal rules the overestimation of total costs is often due to errors in the quantity of required emission reductions which, in turn, is driven by both baseline and compliance issues. In these cases, the *ex ante* overestimate of total costs is accompanied by an *ex ante* overestimate of total benefits (pollution reductions). At least for EPA and OSHA rules, overestimation of *per unit* abatement costs occurs about as often as underestimation. On the other hand, overestimation of per unit costs seems to occur consistently for those rules that employ economic incentive mechanisms.

We find numerous instances in the case studies where actual compliance costs are lower than predicted costs because of unanticipated use of new technology. Thus the case studies support the usual explanation for regulatory cost overestimates--unanticipated technological innovation. We might further ask whether there are particular features of rules that encourage innovation, and here we note the importance of flexibility--especially regarding when, how, where and by whom emission reductions are to be made. The more flexible rules are, the more difficult it is for regulators or anyone else to anticipate the technical responses to regulation and what the costs might be. Of course, the most flexible emission reduction policies involve substantial use of economic incentives, and we note that for all the economic incentive policies in our sample the cost was overestimated or the quantity of emission reductions was underestimated. In fact, the disproportionately large share of market-based rules in our data raises concerns that we may have inadvertently selected rules especially prone to cost overestimation.

Unanticipated innovation is not the only explanation for overestimates of direct regulatory costs. The case studies, as well as discussions with regulators and academic experts, also generated support for four other hypotheses: quantity errors (which may imply that benefits are overestimated), changes in the regulation after the cost estimate is prepared, use of maximum cost estimates, and asymmetric error correction. Some of these explanations, such as the tendency to estimate maximum costs, also support the notion that direct costs are overestimated. However, other explanations imply that the implemented regulation is not the one for which the cost estimate is prepared. In that case, the regulation is not the bargain it might appear to be just looking at the cost comparison.

In any case, the tendency to overestimate compliance costs seems to arise from both the pressures of regulatory politics and certain practices of cost estimation and rulemaking. Our data set is too small to sort out the relative importance of these hypotheses, or of others that did not suggest themselves to us. To gain further insights into the biases of regulatory cost estimates, we believe it is critical that the universe of credible *ex post* studies be expanded. To sort out the relative significance of these and other possible explanations of cost mis-estimation, it is also important to study more closely the rulemaking and cost estimation process, as Hahn and others have recommended.

Some may see these findings as undermining the value of rigorous *ex ante* analysis of the costs of regulation. We strongly disagree with such an interpretation as it ignores the useful role that cost estimation can serve in the rulemaking process. Cost estimation helps regulators conduct a disciplined process of thinking through the full ramifications of a rule. As noted earlier, findings of high cost can also motivate a search for regulatory options that lower costs, often at little or no reduction in benefits.

It should come as no surprise that *ex ante* estimates can be useful in the rulemaking process without necessarily providing good predictions of costs *ex post*. After all, the cost estimate is usually an input to the rulemaking decision, not an output intended to be judged on its own merits. Still, there is much to be said for making the final estimate as accurate as possible. In order to assure that the public has the Agency's "best estimate" of the regulation, there are some fairly simple changes to cost estimation procedures that could be adopted. Since a number of statutes appear to encourage the development of cost estimates that reflect a maximum rather than a mean, regulatory agencies could issue a "best estimate" along with the statutorily preferred cost estimate. Likewise, they could ensure that any changes in the rule made subsequent to publication of the cost estimate would be manifest in a revised cost estimate.[19] Changes of this sort this would not only provide more reliable information to the public but they would also serve to enhance the credibility--and hence the usefulness--of cost estimates in the regulatory process. Indeed, discovering how and when to adjust *ex ante* estimates provides the strongest possible justification for more credible *ex post* studies--a research activity that we believe merits greater emphasis.

[19] Currently, revised cost estimates are prepared for some rules but not others.

## Appendix A: Summary of Case Studies

| | Date of ex ante study | Source for ex post comparison | Quantity reduction | Unit cost of pollution reduction | Total Cost | Comments |
|---|---|---|---|---|---|---|
| **Leaded Gas** | 1985 | Nichols (1997) | Underestimated | Accurate | Accurate | Costs of the rule were never reestimated. The more rapid than expected phase-out of leaded gasoline suggests that costs may have been lower than expected. |
| **Dinoseb** | 1986 | Gianessi and Phillips (1998) | Accurate | Underestimated | Overestimated * | After dinoseb was banned, EPA granted emergency exemptions to peanut farmers, allowing them to use paraquat. Paraquat was more cost effective than dinoseb, so the result was a net savings. |
| **CFCs** | 1986 | Hammitt (1997) | Accurate | Overestimated | Overestimated | Subsequent regulation backed by treaty and legislation expanded the reductions beyond those initially forecast. |
| | 1988 | | Accurate | Accurate | Accurate | Estimates released after the signing of the Montreal Protocol contained lower forecast costs – one scenario was approximately correct; the other was an underestimate. |
| **Aldicarb** | 1988 | Gianessi and Phillips (1998) | Overestimated | Underestimated | Underestimated | Although EPA accurately forecast farmers' behavior following the ban, the substitutes used were far less effective than predicted. EPA reinstated aldicarb's use in some locations. |
| **SO2 Phase I** | 1990 | Smith et al (1998), Carlson et al (1998) | Accurate | Overestimated | Accurate | The effect of rail deregulation allowing more low sulfur coal to move East was not adequately accounted for. Realized emissions have been lower than expected. However, the predicted total costs of Phase I were correct because of the high capital costs of extensive Phase I scrubbing and contributions to the bank. |
| **SO2 Phase II** | 1990 | EPRI (1997), Carlson et al (1998) | Overestimated | Overestimated- | Overestimated | Recent modeled estimates indicate that costs for Phase II were overstated. Emissions in Phase II are expected to be higher than initially forecast because of Phase I banking. |

## **Appendix A: Summary of Case Studies** (cont'd)

| | Date of ex ante study | Source for ex post comparison | Quantity reduction | Unit cost of pollution reduction | Total Cost | Comments |
|---|---|---|---|---|---|---|
| **NOx (Clean Air Act)** | 1990 | Burtraw (1998b)) | Accurate | Accurate | Accurate | The program did not involve a fixed emissions cap; instead it involved a reduction in the emission rate. The agency overestimated electricity demand growth and therefore overestimated baseline emissions. Although costs were about accurate, there was a resulting modest (less than 25%) overstatement of total emission reductions. |
| **I/M** | 1992 | Harrington et al. (1999) | Overestimated | Underestimated | ? | Vehicle repair not as effective as anticipated in achieving emissions reductions; therefore realized reductions were lower than expected. *Ex ante* study envisioned nationwide program applying to 56 million vehicles. So far program has only been implemented in four states. |
| **Reformulated Gas** | 1993 | Anderson (1997) | Overestimated | Accurate | Overestimated* | EPA's predicted cost differentials appear to be reasonably accurate for the largest markets. Public concern about health effects of MTBE led to some states dropping out of the program. |
| **Coke Oven emissions (EPA)** | 1993 | Graham (1997) | Accurate | Underestimated | ? | Preliminary indications are that EPA rule has contributed to the trend of increasing coke imports. |
| **Asbestos** | 1972 | Priest, Bengali (1981), cited in Mendeloff (1988) | Overestimated | Accurate | Overestimated | *Ex ante* forecast overestimated initial exposure levels. |
| **Vinyl Chloride** | 1974 | OTA (1995) | Accurate | Overestimated | Overestimated | Estimates of direct costs are 20-25% of those predicted. Price increases are observed, but even if these costs are included the *ex ante* was an overestimate. |
| **Coke Ovens (OSHA)** | 1975 | Arthur Anderson & Co. (1979), cited in Mendeloff (1998) | Overestimated | Underestimated | Overestimated* | Although total expenditures were far below those predicted by OSHA, this was in large part due to incomplete compliance |
| **Cotton Dust** | 1976 | Viscusi (1992)<br>OTA (1995) | Overestimated | Overestimated | Overestimated | *Ex ante* estimate overstated the number of workers affected by the regulation. In addition, after promulgation the textile industry modernized in response to foreign competition, enabling dust control to be achieved at a lower cost. |

## Appendix A: Summary of Case Studies (cont'd)

| | Date of ex ante study | Source for ex post comparison | Quantity reduction | Unit cost of pollution reduction | Total Cost | Comments |
|---|---|---|---|---|---|---|
| **Occupational Lead** | 1978 | OTA (1995) | Overestimated | Underestimated | Overestimated* | Al though costs were lower than predicted by OSHA, exposure reductions were achieved through hygiene and worker protective gear, as opposed to the engineering approaches the agency envisioned. The collapse of lead prices after 1979 resulted in a shakeout of the industry, further lower total compliance costs. As of 1994 lead exposure levels still exceeded permissible exposure levels of the regulation. |
| **Ethylene Oxide** | 1984 | OTA (1995) | Accurate | Accurate | Accurate | Cost slightly higher due in part to overcompliance motivated by long-term exposure and liability concerns. |
| **Formaldehyde** | 1987 | OTA (1995) | Accurate | Overestimate | Overestimate | *Ex ante* estimate overlooked important substitute. |
| **Powered Platforms** | 1989 | OTA (1995) | Overestimate | Accurate | Underestimate | Rule was supposed to generate cost savings. AN economic downturn in the construction industry prevented the total projected savings from being realized. |
| **LEV** | 1990, 1994 | Cackette (1998) | ? | Overestimate | ? | Ex post survey revealed slight overestimate. |
| **Reformulated Gas (CA)** | 1991, 1996 | Cackette (1998) | ? | Overestimate | ? | Per gallon costs were about half those estimated by CARB. Ambient monitoring detected significant improvements in air quality. |
| **RECLAIM (NOx)** | 1993 | SCAQMD (1998) | Underestimate | Overestimate | Overestimate | Price of NOx trading credits significantly lower than forecast. Emissions also lower. |
| **RECLAIM (SOx)** | 1993 | SCAQMD (1998) | Accurate | Overestimate | Overestimate | Price of SOx credits trading slightly lower than forecast. |
| **Singapore Congestion Licensing System** | 1975 | Hau (1992) | Underestimate | Overestimate | ? | Licensing program attempted to reduce morning congestion in central business district. Program was expected to reduce traffic 25-30%. Traffic dropped between one-third and one-half. The program exacerbated congestion in other areas of the city. |

## Appendix A: Summary of Case Studies (cont'd)

| | Date of ex ante study | Source for ex post comparison | Quantity reduction - | Unit cost of pollution reduction | Total Cost | Comments |
|---|---|---|---|---|---|---|
| **Bergen Toll Ring** | 1986 | Hau (1992) | Underestimate | Overestimate | ? | Traffic was projected to fall by 3%; fell 6-7% in the first year. |
| **Ontario Water** | 1988 | OMOE (1996) | Accurate | Accurate | Accurate | Rule covered nine major industrial sectors. Although the total cost prediction was accurate, the estimates for individual sectors varied widely. |

*Compliance level substantially different than envisioned in the RIA

## APPENDIX B: DESCRIPTION OF CASES

**Regulation:** EPA Phase-out of leaded gas -- 47 FR 49322
**Source:** Albert Nichols. "Lead in Gasoline," in Economic Analysis at EPA: Assessing Regulatory Impact" in Morgenstern (1998)

The costs of the rule were predicted to be around $600 million year in increased refining costs (1983$). There has not been a retrospective analysis of the rule's costs but evidence indicates that EPA's analysts correctly forecast the costs or even overestimated them. First, refiners were able to reduce production of leaded gasoline much more quickly than anticipated. Second, the price differential between leaded and unleaded gasoline narrowed considerably after promulgation, in accordance with EPA's analysis. A retrospective analysis is complicated by the fact that world oil prices plummeted following the rule, swamping any effect that the regulation may have had.

**Regulation:** EPA 1986 dinoseb ban
**Source:** Gianessi and Phillips (1998)

The retrospective study looked at the effect of the dinoseb ban on peanut farmers. In 1986, the EPA announced the emergency suspension of all registrations of dinoseb. The EPA predicted that the ban would result in a loss of about $70 million in the first year due to reduced peanut yields. Following the ban, the agency granted emergency exemptions for farmers in several southern states, allowing them to apply paraquat to their peanut crops. Because paraquat was more cost-effective than dinoseb, there was a cost-savings of around $400,000/year. While this eliminated the costs of the ban, it also affected the benefits; increased paraquat use has environmental costs.

**Regulation:** CFC Phaseout
**Source:** James K. Hammitt (1997)

*Ex ante* estimates come from two sources: a RAND report published in May 1986 (16 months before the signing of the Protocol) and an EPA RIA published in August 1988 (11 months after the Protocol). The period between the two studies was one of intense technological research. Hammitt takes the total market price as an estimate of the marginal cost of the consumption restriction. As CFC consumption declined in response to limits placed on the number of permits issued, the total market price increased, tracing out the marginal cost of control.

RAND estimated costs separately for CFC 11, 12, and 113 and provided two estimates, representing upper and lower bounds on expected reduction in CFC consumption. Expected reductions were reported as a function of price. At prices of $6-8/kg, consumption of both CFC-11 and CFC-12 were about 40 percent to 60 percent below the forecasted baseline. On the other hand, CFC-113 was accurately forecasted especially for modest and large reductions. In the aggregate, the costs of the phase-out were overestimated by RAND.

EPA provided two scenarios: slow and fast implementation. EPA underestimated control costs, although the pessimistic estimate was reasonably accurate for 40 percent - 60 percent reductions achieved in 1990 and 1991. Hammitt attributes some of EPA's underestimate to the accelerated phase-out brought about by amendments to the Protocol. The increased phase-out meant that the reductions happened much sooner than expected, before new low-cost technologies could be introduced.

**Regulation:** EPA's 1988 aldicarb ban
**Source:** Gianessi and Phillips (1998)

In 1988, the EPA estimated that the total costs of a complete aldicarb ban would equal $135 million. About 15 percent of total aldicarb applications were applied to potatoes. Although EPA accurately predicted the responses farmers made to the ban, they overestimated the effectiveness of substitutes in controlling potato pests. The resulting spread of leaf roll virus may have by itself led to yield losses in excess of $100 million. EPA reinstated aldicarb's use in some locations.

**Regulation:** Title IV of the Clean Air Act -- SO2 reductions (Phase I)
**Source:** Carlson et al. (1997); Smith, Platt and Ellerman (1998)

The sulfur dioxide provisions of the Clean Air Act are often cited as an example of dramatic *ex ante* overestimation of the costs of environmental regulation. Claims that S02 allowances are trading for less than one-tenth of the predicted price are overstated, according to Smith, Platt and Ellerman (1998) and Burtraw (1998a). Burtraw places the correct comparison at a forecast price of $250/permit and a realized price of around $125/permit. There are two *ex post* studies that estimate total costs of the regulation. Carlson et al. is an econometric study that estimates total annual Phase I costs of the program in 1995 were $832 million in 1995 dollars and marginal costs and marginal costs of $180 per ton of abatement. Ellerman et al. is a survey that places 1995 annual costs at $726 million. There are a number of *ex ante* studies that can be used for comparison; ICF (1990) is the study most relevant to the passage of Title IV and also represents the low end of the range of cost estimates for the regulation. ICF (1990) predicted annual costs of between $450 million and $860 million and marginal costs of $199-226/ton. The lower than predicted marginal costs are explained by technological improvements in scrubbing, innovations allowing for greater use of low-sulfur coal, and railroad deregulation that substantially reduced the costs of transporting low-sulfur Western coal. These factors also contributed to a substantial reduction in baseline emissions. Smith, Platt, and Ellerman report that there has been greater "overcompliance" (excess SO2 reductions) than had been expected prior to the regulation.

**Regulation:** Title IV of the Clean Air Act -- SO2 reductions (Phase II)
**Source:** Carlson et al. (1997); EPRI (1997)

Phase II of the program begins in the year 2000, so new estimates are not *ex post* but revised *ex ante*. ICF (1990) forecast annual costs of $1.6-5.3 billion/year for 2010 (full implementation of Phase II), with marginal costs of $564-740 per ton. Carlson et al.'s preferred estimate is $1.0 billion a year and a marginal cost of $291/ton. EPRI's updated costs for the program range from $1.1-1.8 billion a year and marginal costs of $276-498 per ton. Higher than expected overcompliance in Phase I implies that Phase II reduction between 2000 and 2010 will be less than expected due to banking.

**Regulation:** Title IV of the Clean Air Act -- NOx reductions
**Source:** Burtraw (1998b)

The program did not involve a fixed cap. Although the *ex ante* estimate overestimated baseline emissions, quantity reductions and costs were accurately forecasted.

**Regulation:** Enhanced I/M (57 FR 52950, November 5, 1992)
**Source:** Harrington, McConnell, and Ando (1999)

An estimated 56 million vehicles in "serious" and worse nonattainment areas were to implement the "high option" program, consisting of centralized IM-240 tests, evaporative emission tests and repair of all 83 and later model-year vehicles. In 1995 EPA was prevented by Congress from requiring centralized testing, and the states were allowed much greater latitude in coming up with a substitute program. Only five states have so far implemented the IM-240 test, usually with weaker emission standards than examined by EPA in the RIA. On a per-vehicle basis, the costs (including testing cost, fuel savings, motorist inconvenience cost and repair cost) of the program slightly exceed the *ex ante* estimates, but the emission reductions achieved are much smaller.

**Regulation:** EPA 1994 reformulated gas regulation -- 59 FR 7716
**Source:** Robert Anderson and Richard Rykowski (1998); "Reformulated Gasoline" in Morgenstern (1998)

The EPA RIA predicted an average 2.3 cents per gallon increase in refinery costs for reformulated gasoline. In 1995, the price differentials were slightly higher than predicted due to a temporary increase in methanol prices. It appears that EPA correctly forecast the price increases for the larger markets. In June 1998, the price differential in California was 2.0 cents. For New York it was 2.3 cents and for Texas it was 1.8 cents. Prior to the regulation there were fears about a shortage of RFG but there was an initial glut. A number of states opted out of the program responding to consumer concerns about cost and the health effects of MTBE.

**Regulation:** EPA Coke Oven standard
**Source:** Graham (1997)

Graham did not provide a retrospective reestimation of the total costs of the rule. Anecdotal evidence shows that the technological modifications envisioned by the EPA have not taken place. Instead, there is evidence the rule has contributed to continuing the trend of increasing coke imports. As Graham notes, "the net effect on worldwide emissions from coke production is not likely to be favorable, although residents living near U.S. coke plants will have cleaner air to breathe."

**Regulation:** OSHA 1972 Asbestos Standard -- 37 FR 3155
**Source:** Mendeloff (1988)

Mendeloff reports that a 1974 reanalysis by an independent academic suggested that OSHA's consultant had doubled the true cost of compliance with OSHA's 2-fiber standard because the consultant had assumed that exposures were considerably higher than they really were. The reanalysis placed the annual costs at $75 million in 1970 dollars. A retrospective study conducted in 1980 estimated that costs were in line with the academic estimate.

**Regulation:** OSHA 1974 Vinyl Chloride Standard –39 FR 35890
**Sources:** Office of Technology Assessment (1995), Mendeloff (1988)

Mendeloff's review describes the vinyl chloride standard as providing "the most blatant overestimates of compliance costs." OSHA's consultant argued that the proposed 1 ppm standard was infeasible, but placed the costs of less stringent standards at around $100 million a year in 1974 dollars. OSHA went ahead and promulgated the 1 ppm standard. A subsequent study by researchers from the Wharton School of Business put compliance costs for the 1 ppm standard at around $20 million a year. According to OTA, the most credible *ex ante* estimates for the 1 ppm standard came from OSHA's technical consultant who placed total costs of the rule at $1 billion in 1974 dollars. OTA's retrospective analysis estimated total spending to be around a quarter of this amount--$228 million to $278 million.

**Regulation**: OSHA Coke Oven standard -- 41 FR 46741
**Source**: Mendeloff (1988)

OSHA's contractor estimated a range for the standard of $200 million to $1 billion in 1975 dollars. No retrospective study has looked at the total costs of the regulation but anecdotal evidence points to an *ex ante* overestimate of total costs. A survey conducted by Arthur Anderson for the Business Roundtable obtained information from three steel firms that were affected by the regulation. OSHA's consultant had predicted that the three firms would spend around $91 million on the regulation; the survey found that they had spent only $5-7 million. However, Mendeloff states that a major reason for these low expenditures was incomplete compliance with the regulation.

**Regulation:** OSHA 1978 Cotton Dust standard -- 43 FR 27350
**Sources:** Office of Technology Assessment (1995), Viscusi (1992)

OSHA's RIA placed the textile manufacturing sector's cost at $280.3 million a year in 1982 dollars. OTA's retrospective study estimated actual spending to be approximately a third of this amount--$82.8 million annually. Viscusi breaks out the costs into total capital costs and annual operating costs. The prospective analysis predicted total capital costs of $1.4 billion and annual operating costs of $173 million (1982 $). A retrospective analysis placed capital costs at $269 million and operating costs at $29 million/year. A key reason that costs were overestimated according to OTA was that the textile industry modernized in the 1980s in response to foreign competition, making it less costly to achieve dust control. In addition, Viscusi cites some technical errors in the original analysis, such as overestimating the number of plants and workers affected by the standard.

**Regulation:** OSHA 1978 Occupational Lead -- 43 FR 52952
**Source:** Office of Technology Assessment (1995)

OSHA estimated that meeting the 50 $\mu g/m^3$ standard would cost a total of $150 million for capital spending and 1.6 cents/lb for operating/maintenance expenses (1992 dollars). According to OTA, actual spending through 1994 amounted to only $20 million for capital expenses and between 0.5 and 1.0 cents/lb for operating and maintenance. Exposure reductions were achieved through hygiene and worker protective gear, as opposed to the engineering approaches the agency envisioned. The collapse of lead prices after 1979 resulted in a shakeout of the industry, further lowering total compliance expenditures. As of 1994, air lead levels still exceeded the permissible exposure levels of the regulation.

**Regulation:** OSHA 1984 Ethylene Oxide standard -- 49 FR 25734
**Sources:** Office of Technology Assessment (1995)

Regulation affected a half-dozen industries; retrospective study examined hospital sector, the industry with the vast majority of exposed workers. OSHA's RIA predicted total compliance costs to be $23.7 million annual in 1982 dollars. OTA's retrospective assessment found total spending to have modestly exceeded this estimate, but this was due mainly to overcompliance motivated by long-term health concerns and managers' fears of possible future tort liability claims.

**Regulation:** OSHA 1987 Formaldehyde standard -- 52 FR 46168
**Sources:** Office of Technology Assessment (1995)

The RIA estimated the compliance costs of the metal foundries sector to be $11.4 million annually in 1987 dollars. OTA estimates that actual costs were about half--$6.0 million. A key reason for this is that the RIA overlooked the possibility of industry using already existing low-formaldehyde substitutes instead of more expensive technological solutions, such as increasing ventilation or enclosure approaches.

**Regulation:** OSHA 1989 Powered Platforms safety standard --54 FR 31408
**Sources:** Office of Technology Assessment (1995)

Powered platforms are used in the construction of high-rise buildings. OSHA's amended regulation allowed for greater flexibility in choosing technology and therefore was expected to generate cost savings of about $1.7 million a year in 1989 dollars. A downturn in the construction industry meant that the anticipated cost savings were not realized in full. As a result, OTA estimates the savings fell to a best case of $600,000/year or as low as a *net cost* of $400,000/year.

**Regulation:** Low Emission Vehicles -- California Air Board
**Source:** Presentation by CARB's Tom Cackette, July 1998

In 1990, CARB predicted fleet average incremental cost for LEV technology to be $170. By 1994, the number had fallen to $114 (compared to an industry estimate of $788). According to a survey conducted by CARB in 1998, the actual incremental cost of LEV technology was $83.

**Regulation:** Reformulated Gasoline in California -- CA Air Board
**Source:** Presentation by CARB's Tom Cackette, July 1998.

In 1991, CARB predicted that reformulated gas would lead to a price increase of 12-17 cents/gallon. In 1996, CARB predicted the differential to be 10 cents/gallon. In 1998, the actual differential was 5.4 cents a gallon.

**Regulation:** NOx trading in California
**Source:** South California Air Quality Management District (1998)

The prices of NOx trading credits are significantly lower than projected. In October 1993, the AQMD predicted that NOx Reclaim Trading Credits (RTCs) would trade for $11,257 in 1999. In 1997, 1999 prices for 1999 credits were around $1,800. Credits were distributed with the objective of matching the emission reductions that would have been achieved under a command and control policy. Realized emission have been below those projected under command and control.

**Regulation:** SO2 trading in California
**Source:** South California Air Quality Management District (1998)

The prices of SO2 RTCs were also overestimated but not as dramatically as for NOx. According to the 1993 AQMD predictions, SO2 RTCs were projected to cost $2,970 in 1998 and $2,882 in 1999. In 1997, 1998 and 1999 RTCs were trading for $1100 and $2400, respectively.

**Regulation:** Singapore Area Licensing Scheme
**Source:** Hau (1992)

The program limited access to an area of the Central Business District (CBD) during morning rush hour. Automobile owners were required to purchase a special sticker in order to enter the CBD between 7:30 and 9:30 a.m. Taxis, buses, carpools and commercial vehicles were exempt from the rule, which was expected to reduce overall traffic volume by 25 percent. Motor car traffic dropped by three-quarters, while overall traffic volume dropped by between a one-third and one- half, reflecting a shift to the exempt classes of automobiles as well as motorcycles. Several vehicles were taken off the exempt list and charges for motorcycles were introduced. Increased congestion was observed in other parts of the city, as motorists rerouted their commutes.

**Regulation:** Bergen Toll Ring
**Source:** Hau (1992)

Following Singapore, Bergen, Norway was the second city to charge motorists for entering the Central Business District (CBD). Traffic was expected to drop 3 percent, but dropped 6-7 percent in the first year. Car occupancy increased slightly; it was not clear whether there was a shift toward public transport.

**Regulation:** Water monitoring in Ontario
**Source:** Ontario Ministry of the Environment and Energy (1995)

As part of the Municipal-Industrial Strategy for Abatement, regulations were promulgated that required intensive monitoring of industrial wastewater in nine major industrial sectors. The total cost of the monitoring program was predicted to be $43.6 million in 1988 Canadian dollars. The estimate was thought to be accurate +/- 20 percent. A retrospective study conducted in 1996 found the costs to be $50.9 million, a difference of about 14 percent. Although the total cost prediction was accurate, the estimates for individual sectors varied widely. For example, the costs to the metal mining sector were overestimated by about 248 percent, while the costs to the electric power sector were almost twice as large as predicted.

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