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Do Regulators Overestimate the Costs of Regulation?

R. David Simpson

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Abstract

It has occasionally been asserted that regulators typically overestimate the costs of the regulations they impose. A number of arguments have been proposed for why this might be the case, with the most widely credited one being that regulators fail sufficiently to appreciate the effects of innovation in reducing regulatory compliance costs. Most existing studies have found that regulators are more likely to over- than to underestimate costs. Moreover, the ratio of *ex ante* estimates of compliance costs to *ex post* estimates of the same costs is generally greater than one. In this paper I argue that neither piece of evidence necessarily demonstrates that *ex ante* estimates are biased. There are several reasons to suppose that the distribution of compliance costs would be skewed, so that the median of the distribution would lie below the mean. It is not surprising, then, that most estimates would prove to be too high. Moreover, we would expect from a simple application of Jensen's inequality that the expected ratio of *ex ante* to *ex post* compliance costs would be greater than one. In this paper I propose a regression-based test of the bias of *ex ante* compliance cost estimates, and cannot reject the hypothesis that estimates are unbiased. Despite the existence of a number of papers reporting *ex ante* and *ex post* compliance cost estimates, it is surprisingly difficult to get a large sample of such comparisons. My most salient finding does not concern the bias of *ex ante* cost estimates so much as their inaccuracy and the continuing paucity of careful studies.

1. Introduction

Since the Reagan Administration regulatory agencies in the United States have been required to perform cost-benefit analyses of high-profile regulations.[1] Many other nations have also instituted similar requirements for regulatory impact analyses (Radaelli 2005). How accurate have such *ex ante* estimates of the costs and benefits of environmental, health, product, and other regulations proved to be?

With respect to the costs of regulatory compliance, available evidence seems to suggest that the answer is "not very". The cost estimates offered by regulators are generally higher than are *ex post* estimates of compliance costs.[2] A review of ten surveys, each of which reviews the results of a number of different case studies, finds that in each survey *ex ante* estimates of compliance costs exceed *ex post* estimates in a majority of instances. It is, admittedly, a risky venture to attempt to make comparisons across studies of different regulations from different regulators for different industries at different times, and sometimes in different places. If, however, one performs what may seem a natural test of the overall accuracy of regulatory cost estimates – averaging the ratio of *ex ante* to *ex post* cost estimates – she finds that the average ratio exceeds one, and often is considerably greater than one.

A number of hypotheses have been advanced to explain why *ex ante* cost estimates are often too high. Some emphasize that regulators do not have an incentive to conduct careful cost estimates: if it appears that a regulation will pass a cost-benefit test anyway, there is no real motivation to prepare a careful study, or, perhaps more importantly, to inflame opposition from the affected entities by venturing more controversial estimates. Other authors note that the "first draft" regulations for which compliance costs are predicted are often more stringent than those eventually passed and with which regulated entities must comply (or, to introduce another closely related hypothesis, with which they may not comply in practice). The explanation that has received the most attention and which seems to generate the most credence, however, is that regulators fail to account for innovation. As Lisa Heinzerling, former Associate Administrator in EPA's Office of Policy wrote (albeit in 2002, before coming to EPA), "Regulatory analysis is notorious for failing to take into adequate account the technological innovations that ultimately make many regulations cheaper to implement than regulators anticipate". An anonymous commentator from the Center for Progressive Reform opined that "There is lots of good reason [*sic*] to believe the *ex-ante* estimates . . . are systematically biased," and went on to note that reliance on industry data could account for the bias in regulators' estimates, as well as the difficulty of predicting technological innovation (*Inside EPA* 2011).

So, it seems that there are good reasons to suppose that regulators will overestimate the costs of compliance with environmental regulation, and compelling evidence that their cost estimates are biased.

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[1] In practice, this means regulations having an effect on the economy of $100 million or more per year, or designated as "significant" by the Office of Management and Budget (OMB).

[2] We describe the studies in the following section. An exception in one respect is Hodges (1997), who focuses on the cost estimates offered by affected industries, rather than those prepared by government agencies. Not surprisingly, Hodges finds that such estimates are especially inflated.

Or are they?

In this paper I suggest that the evidence is not as clear-cut as it has seemed to some commentators. My main arguments are statistical. Neither of the procedures that have been employed to evaluate the accuracy of *ex ante* cost estimates in the existing studies provides a valid test to determine whether or not *ex ante* cost estimates are biased. The fact that most *ex ante* cost estimates exceed *ex post* estimates would only indicate a bias if it were reasonable to suppose that the distribution of ex ante estimates were symmetric. I offer reasons to suppose *a priori* that they are not.

The fact that the average ratio of *ex ante* to *ex post* estimates exceeds one is also not unexpected. Here the argument is very simple. Holding the numerator of a fraction fixed, a fraction is a convex function of its denominator. Because *ex post* costs will sometimes be lower than their unbiased expectation, we would *always* expect the ratio of *ex ante* to *ex post* estimates to be greater than one if the *ex ante* estimates are unbiased– this is just an application of Jensen's inequality. If there is some probability that *ex post* costs are very low, then some of the ratios of *ex ante* to *ex post* estimates may explode.

It is worth repeating before suggesting a better procedure for evaluating the accuracy of *ex ante* cost estimates that any procedure involving comparisons between *ex ante*/*ex post* estimate pairs from different industries, regulations, time periods, countries, etc., must rest on heroic assumptions. Moreover, it is worth remarking that I have been referring to *ex ante* and *ex post* cost "estimates". We can rarely be confident that we have observed the actual realization of *ex post* costs.[3]

For the sake of argument, however, let us make the heroic assumption that we can regard different observations of *ex ante* and *ex post* compliance cost pairs as being in some sense generated by comparable processes. The null hypothesis is that the law of iterated expectations holds: the expectation of the best estimate that can be made now of the best estimate that can be made later is the expectation of the best estimate that can be made later. Thus the *ex ante* estimate should be equal to the *ex post* estimate plus an uncorrelated prediction error term. This hypothesis can be tested by regressing *ex ante* estimates on a constant term and the corresponding *ex post* estimates. The null hypothesis is that the intercept term of this regression will be zero and the slope one. I cannot reject this hypothesis in a sample of 18 *ex ante*/*ex post* compliance cost estimates.

What should we conclude from this exercise? First and most obviously, that existing studies do not establish that regulators generate biased estimates of costs. To be fair, it should be

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[3] An exception to this observation might be found in the case of regulations that establish tradable permit markets. Then we might compare the anticipated cost of permits with their actual values. The unexpectedly low price of SO_2 permits under the Clean Air Act Amendments of 1990 has become something of a *cause célèbre*, for example (see, e. g., Harrington, *et al*. 2000). It certainly supports the narrative that regulators failed to anticipate innovations in compliance. I have not included cost estimates that report only the prices of permits in the statistical analysis below, as I have attempted to confine attention to studies that venture estimates of *total* compliance costs, which would include a) investment expenditures; and b) some measure of the range of production units or units of output affected.

noted that this is not really the claim of most of the studies themselves so much as that of some second-hand summaries of their findings. The authors of most studies are appropriately circumspect in presenting their results and noting their limitations.[4] This conclusion has an obvious policy implication. If policy makers were tempted to conclude that regulatory cost estimates are biased and should be revised downward so as to provide a more liberal benefit-cost test of proposed regulation, this would appear to be premature.

There is, however, perhaps a more important conclusion to be drawn from this exercise. The problem with existing *ex ante* cost estimates may not be that they are *biased* so much as that they are *bad*. While it would be nice to have estimates of the costs of regulation that were *right* on average, it would be even more comforting to have estimates that were *close* on average.

Finally, while the conclusion that "more research is needed" is certainly hackneyed (and in many instances self-serving), if ever it were justified, this would be an instance. One very surprising finding that comes out of a careful review of existing studies is that existing studies are very limited. This is not to say that previous authors have not been careful and diligent. They certainly have. But such fundamental questions as "what constitute costs?" have been answered in different ways by different authors. Greater methodological standardization would facilitate comparisons and conclusions of the type I have attempted to draw, and would provide better guidance for policy. Moreover, one finds on closer inspection that many existing studies do not record the kind of quantitative information that facilitates comparison. The reader may have been surprised to read above that, from among the scores of cases comparing *ex ante* with *ex post* costs of compliance, I have assembled a sample of only 18 usable observations. Authors of some studies have – often of necessity – confined themselves to qualitative assessments. One also finds that several surveys (such as this one) merely recombine existing studies rather than generating new data. More primary data collection and analysis would certainly be useful.

This paper is presented in five sections, including this introduction. The next section reviews the literature on the accuracy of *ex ante* cost estimates. Following that, I offer arguments for why the measures reported in the existing literature – the frequency with which *ex ante* costs are overestimated and the ratio of *ex ante* to *ex post* cost estimates – do not necessarily shed light on the question of whether ex ante cost estimates are biased. In the fourth section I propose an alternative statistical test and report its results. A fifth section briefly presents conclusions.

2. Previous studies

A number of researchers have studied the accuracy of *ex ante* estimates of the costs of environmental and other forms of regulation in the light of *ex post* estimates of such costs (I will devote some considerable attention later in this paper as to how and why the two might differ). In the interest of brevity I will distinguish between studies of the disparity between *ex ante* and *ex post* estimates of costs and *surveys of studies of* such disparities. I will focus on the latter.

[4] Moreover, at least some reviewers of the literature more generally come to very even-handed conclusions. Hahn and Tetlock (2008) write that while allegations of bias are often encountered, the evidence as to *which way* (if either) the bias tends is less clear-cut.

There are now quite a number of reports whose authors have taken as their data the results of earlier studies of particular regulations in particular industries and tried to evaluate the accuracy of such studies generally. As we will see below, one of the challenges of such undertakings is to define what it means for *ex ante* cost estimates to be "accurate". Existing studies generally report accuracy in terms either of the fraction of studies that overestimate costs, or in terms of the ratio of *ex ante* to *ex post* cost estimates. Broadly speaking, existing studies find that overestimates are more common than underestimates, while the ratio of *ex ante* to *ex post* estimates tends to be greater than one.

The first study of which I am aware devoted specifically to the consideration of the accuracy of *ex ante* projections of the costs of regulation was conducted for EPA by the consulting firm of Putnam, Hayes, and Bartlett and completed in 1980 (hereinafter, "PHB 1980"). The study compared EPA and industry *ex ante* estimates of required capital expenditures for five rules passed in the 1970's with actual capital expenditures. In four of five cases industry overestimated capital costs, while in three of five cases EPA overestimated capital costs for the period from 1974 – 1977. The PHB results are somewhat more ambiguous for a sixth case study, in which EPA and industry estimates of the effects of environmental regulations on new car prices were compared.

The next major study of the accuracy of cost projections was conducted in 1995 by the Office of Technology Assessment (OTA). OTA did not consider environmental regulations, but its study of the accuracy of cost projections of Occupational Safety and Health Administration (OSHA) regulations may have implications for the accuracy of regulatory cost estimation more generally. OTA considered eight regulations in chemical, manufacturing, and service industries enacted between 1974 and 1989. In all cases in which numerical estimates were hazarded estimated costs exceeded actual costs. In two industries the OTA report suggests that costs may actually have been negative: in finding ways to reduce risks, producers may actually have identified processes that operate more efficiently. Such claims would substantiate Michael Porter's (1991) hypothesis, that firms that operate under tougher environmental regulation can actually be more competitive in world markets.

In 1997 Hart Hodges published a study of twelve environmental and workplace safety regulations initiated between the 1970's and 1990's (Hodges 1997; the results are also summarized in Goodstein and Hodges 1997). In each instance *ex ante* estimates of costs were greater than were costs recorded later; in eleven of twelve cases, *ex ante* cost estimates were more than double costs realized *ex post*. Hodges focuses on industry's rather than regulators' estimates of costs. Inasmuch as industry will, in general, have a powerful incentive to overstate costs, the discrepancies Hodges identifies are not surprising.

A very thorough comparison of *ex ante* to *ex post* estimates of costs was conducted in 2000 by Winston Harrington, Richard Morgenstern, and Peter Nelson. The researchers considered 28 regulations written by EPA, OSHA, and a handful of other regional and international regulators. A number of different industries were covered. *Ex ante* cost estimates were considered "accurate" if they were within ± 25% of *ex post* values, and either too high or too low if they fell outside this range. By this standard total costs of regulation were overestimated in 15 instances, underestimated in only three, and deemed reasonably accurate in

the remaining 11. Harrington *et al*. distinguish between *total* and *unit* costs of regulation (the numbers I have just reported are for "total" cost estimates). The latter refer to the costs per unit of output or the cost per plant. Total cost is per unit cost times output or number of plants affected. Harrington, *et al*., find that unit costs tend to be overestimated as often as they are underestimated, in contrast to total cost estimates. I will discuss below some reasons for which this might be the case.

The next major retrospective study of the costs of regulation was completed in 2005 by the Office of Management and Budget (OMB 2005). OMB reviewed 47 regulations initiated between 1976 and 1995. EPA issued 18 of the regulations in the OMB sample, the most of any of the five federal agencies included in the study (the others were the National Occupational Safety and Health Administration (13 regulations included), the National Highway Traffic Safety Administration (8), the Department of Energy (6) and the Nuclear Regulatory Commission (2)). As is generally the case with estimates of regulatory costs, the sample was determined by the availability of data, not by any attempt to generate a random cross-section of regulatory activity. The results of the OMB study are less striking than those of some other researchers. Of 40 regulations for which comparable *ex ante* and *ex post* data are available, 16 *ex ante* projections overestimated cost, 12 underestimated them, and 12 were approximately accurate. The OMB study was not completely independent of earlier work, however: for instance, nine of the studies in its sample were adopted from Harrington, *et al*. 2000.

At least three studies have been conducted of the accuracy of *ex ante* cost measures in other countries (in addition, Harrington *et al*. 2000 includes three examples drawn from Singapore, Norway, and Canada among their 28 case studies). While such inquiries obviously consider costs generated under different legal and regulatory structures than prevail in the U. S., they may still be useful in interpreting general approaches to regulatory cost estimation. It might also be noted in passing that international standards for the analysis of regulatory impacts have become more similar over time, with the United Kingdom (MacLeod, *et al*., 2006) and the European Union adopting such requirements.[5] A study conducted by the Stockholm Environmental Institute considered the cost estimates presented by industry in regulatory negotiations, and found them to be consistently higher than *ex post* realizations of actual costs (Bailey, *et al*., 2002).

MacLeod, *et al*. (2006) performed a similar analysis of *ex ante* costs in UK rulemaking. The authors of this study adopted the same ± 25% standard as used in Harrington, *et al*., 2000, and found that by this standard the costs of five of eight regulations considered were overestimated, those of two regulations were underestimated, and those of one were approximately on target.

In 2006 Oosterhuis, *et al*. published their estimates of *ex ante* and *ex post* costs of regulation with five EU environmental regulations. They report that in four instances *ex ante* cost estimates exceeded *ex post* costs by a factor of two or more, while the *ex ante* and *ex post*

[5] See Radaelli 2005, however, who notes that "regulatory impact assessments" may still differ significantly from one jurisdiction to another

estimates were roughly the same in the fifth case.[6] Oosterhuis *et al*. also report on an earlier study of costs of compliance with Dutch environmental regulations of the first Dutch National Environmental Policy Plan of 1988, as predicted *ex ante* by Jantzen (1989) and later estimated *ex post* by RIVM (2001). These Dutch studies were, by the standards of the field, unusually accurate. While the costs of five of the eight regulations considered were overestimated, only one *ex ante* estimate was as much as twice its *ex post* realization, and in aggregate the total *ex ante* estimate of slightly over €12 billion was only 13% higher than the *ex post* realization. Oosterhuis *et al*. (2006) credit this unusually accurate performance to the existence of relatively good statistics and studies in the Netherlands.

We will conclude this section with summaries of two studies that considered the accuracy of *ex ante* cost predictions for specific consumer products. Anderson and Sherwood (2002) compare cost estimates for EPA mobile source rules. These include six fuel-quality regulations and eleven vehicle emission standards. In most instances Anderson and Sherwood found that *ex ante* estimates of price increases induced by regulation were greater than actual price changes observed. They also found, however, that EPA estimates tended to be closer to actual price changes than were industry estimates.

Dale, *et al*. (2009) considered the costs associated with the Department of Energy's efficiency regulations on consumer appliances such as air conditioners, refrigerators, and washing machines. This study illustrates the challenges inherent in developing estimates for the costs of regulation for consumer goods. Dale, *et al*. derived their *ex post* cost estimates using hedonic regressions to tease out the separate effects of scale, general technological progress, and more competitive behavior from those of the energy efficiency regulations themselves. Having isolated these effects, the authors found, as have the other studies, that *ex ante* cost estimates generally exceed those developed *ex post.*

3. What does the literature show?

The studies we have reviewed uniformly find that regulators overestimate the costs of regulatory compliance more often than they underestimate them, and that the ratio of *ex ante* to *ex post* compliance cost estimates is, on average, considerably greater than one. While this might seem at first blush to establish that regulators' *ex ante* estimates of the costs of regulatory compliance are biased upward, this assertion does not actually withstand closer scrutiny. I consider the two types of evidence in turn, and show that neither necessarily reveals a bias in estimates.

Skewed distributions

One of the most robust findings in the existing literature comparing *ex ante* to *ex post* estimates of costs is that the former generally exceed the latter. I am aware of no study in which more *ex ante* cost estimates were lower than *ex post* estimates, as opposed to higher, and in many

[6] Oosterhuis *et al*. actually consider six environmental directives, addressing large combustion plants, integrated pollution prevention and control, ozone control, ozone depleting substances packaging, and nitrates, but are unable to develop *ex ante* compliance cost estimation numbers for the packaging directive.

a substantial majority of *ex ante* estimates were higher than the corresponding *ex post* estimates. Can we then conclude that *ex ante* cost estimates are generally biased upward?

The answer would appear to be "No," at least not on the basis of this simple observation alone. An estimate is "biased," by the statistical definition of the term, if its expected value differs from the mean of the population from which it is drawn. It is entirely possible that a majority of observations would be below the mean of the distribution of the population from which they are drawn. The median of a distribution will be below the mean if the distribution is skewed, i. e., if it is not symmetrical about its mean.

Do we have any reason to suppose that the distribution of costs would not be symmetrical? Yes, there are several. First, *total* costs are often estimated by multiplying an estimate of *unit* costs by the *number* of units affected by the regulation (Harrington, *et al*. 2000). Both cost-per-unit and units affected are random variables: the researcher cannot observe the former accurately, while absent perfect understanding of market conditions and drivers, the researcher cannot know the latter with certainty. Suppose that the increase in unit costs and the number of units affected are each distributed independently and symmetrically on nonnegative supports. Then their product will be distributed asymmetrically. Heuristically, there is a small probability that unit costs will be large, and a small probability that the number of units affected will be large. Thus, there is a *very* small probability that the cost of regulation will be *very* large. Under such conditions the distribution of total costs will have a long right tail, and hence, be asymmetric.

A very simple example illustrates the point. Suppose that both the increase in unit costs and the number of affected units are distributed independently and uniformly on the interval [0, 1] (we can always make the supports the same by choice of units of measurement). Then it is easily demonstrated that their product is distributed logarithmically on the interval [0, 1] with probability distribution function $-\ln\theta$. This function has mean ¼ and median of approximately 0.187, and about 59.2% of observations are less than the mean.

Another reason to suppose that the distribution of costs is asymmetric is because the mathematical forms that give rise to such costs are often asymmetrically distributed. It can be shown that if production in a regulated industry can be modeled by a constant returns to scale production function of unpriced, but regulated, emissions and purchased inputs, then the reduction in profits that would result if emissions are required to be reduced by an amount Δe may be approximated as

$$CC \approx \pi \cdot (\Delta e / e), \qquad (1)$$

where $\Delta e/e$ is the proportional change in allowed emissions and π is industry profit per unit of emissions, and π is independent of the level of emissions. This expression will be approximately true for small changes in allowed emissions or if the affected industry is small enough as to have negligible impact on input and output prices.

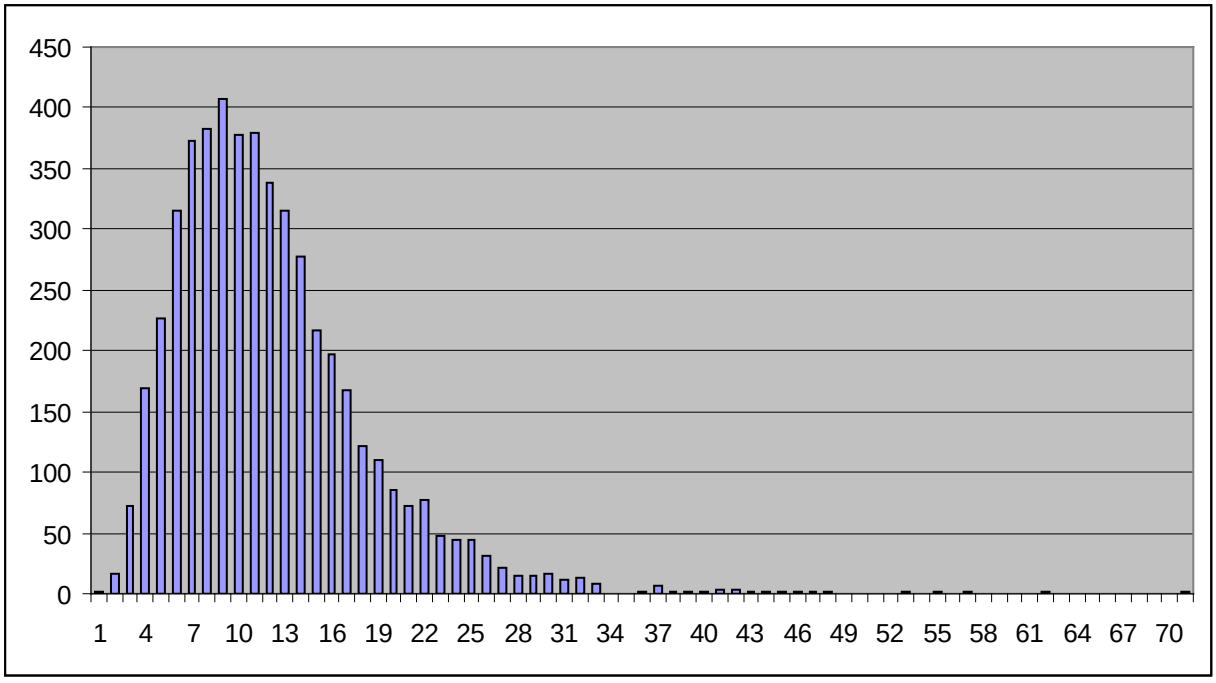
Suppose that we choose a simple form for the production function; consider, for example, the Cobb-Douglas form

$$f(x, e) = x^{\alpha} e^{1-\alpha} \qquad (2)$$

where x is the quantity of purchased inputs employed in production and e the amount of effluent discharged. If p is the price of output and w the price of the input, x (we treat x as a scalar for simplicity; nothing of consequence would change from treating it as a vector), and we normalize the quantity of emissions discharged in the *status quo* ante to one, it can be shown that

$$\pi = (1-\alpha) p^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{w} \right)^{\frac{\alpha}{1-\alpha}}. \qquad (3)$$

If we treat α, p, and w as unknown random variables with independent symmetric distributions, the resulting function π is asymmetrically distributed. This is not surprising, as the central limit theorem applied to the product, rather than the sum, of independent random variables, implies that the product will be lognormally distributed. A histogram for one such distribution is presented below:



α, p, and w are distributed normally with means of 0.75, 1, and 1, respectively, and standard deviations of 0.05, 0.10, and 0.10, respectively. The expectation of the resultant distribution is 0.120, the median 0.106, and 59.1% of observations are less than the mean.

A third reason for supposing that the distribution of costs might be skewed may arise from the attributes of innovation. The story that is often told as to why costs tend to be overestimated is that the people recording estimates tend to discount the possibility of innovation. They do not reflect the high likelihood that much more cost-effective ways of

complying with regulation will be identified. It could well be, however, that while very cost-effective strategies are, in fact, identified *most* of the time, spectacularly costly exceptions could draw the mean cost of regulation considerably higher than the median.

Cost ratios

The fact that *most ex ante* estimates of costs are higher than are the corresponding *ex post* estimates does not necessarily imply that such estimates are biased. In order to make the determination of whether or not estimates are biased, we would need to know whether there are occasional spectacular exceptions in which *ex ante* costs severely *under*estimated actual costs.[7]

There are certainly instances in which the costs of rules have been underestimated. The problem, though, is that we never have repeated samples from the same distribution. There is, in each case, *one* rule whose costs are estimated, yielding *one ex ante* estimate and *one ex post* estimate. It would require some truly heroic assumptions to say that the fact that costs were *under*estimated on a regulation affecting electric utilities, for example, somehow "offsets" the fact that costs were overestimated on rules affecting automobiles and appliances.

Let us suppose, however, that one were prepared to make such heroic assumptions. Many studies note that, for most rules, *ex ante* estimates are a multiple greater than the corresponding *ex post* estimates. What might we infer from such observations?

Again, the frustrating answer may be "not much". To see why, consider a very simple example. Suppose that a rule is being contemplated, and that with 50% probability costs will be 50, while with 50% probability costs will be 150. In expectation, then, costs would be 100. On average, however, the *ratio* of predicted *ex ante* to *ex post* costs will be $\frac{1}{2} \cdot 100/50 + \frac{1}{2} \cdot 100/150 = 1\ 1/3$. Note that the issue here is *not* the symmetry of the distribution of realized costs. Rather, it is that if *ex post* costs are low, the ratio of estimated to realized costs explodes, even if the estimation is unbiased.

The problem may be even worse if it is made more realistic. It is not unreasonable to suppose that costs of regulation in some instances could be near zero, or possibly even negative. While it *is* unreasonable to suppose that *expected* costs of compliance would be negative (if they were, why wouldn't firms make the changes absent regulatory urging?), it is certainly not inconceivable that, once having been induced to consider some innovations, firms would occasionally hit on some solutions that would actually reduce their costs of production and increase their profits (Oosterhuis, *et al*., 2006 raise the possibility that innovations could result in compliance at negative net cost; OTA 1995 suggests that a couple of OSHA rules might have generated negative compliance costs). It is possible, then, that the ratio of *ex ante* to *ex post* estimates would be unbounded.

In short, then, while it may sound troubling to read that *ex ante* cost estimates exceed *ex post* estimates by substantial multiples, such a finding would not establish that *ex ante* estimates

[7] The 2005 OMB study raises another interesting point that is worth considering in passing. We can never observe the accuracy of cost estimates for rules that were never issued.

were unbiased. It could rather, and perhaps counterintuitively, suggest that *no* statistical inferences could be drawn on the basis of such data.[8]

4. Evaluating the accuracy of *Ex ante* cost estimates: An alternative approach

In practice, both *ex ante* and *ex post* estimates of costs are just that – estimates of random variables whose true values remain unknown either because the rule under contemplation has not yet been enacted, in the case of *ex ante* estimates, or because we cannot completely and accurately observe all affected entities' costs of in the case of *ex post* estimates. Somewhat more formally, we could say that any estimate of costs, θ, may be written as $E(\theta \mid \Omega)$, where Ω is an information set available at the time the estimate is made. At a later time a revised estimate of θ might be formed based on an updated information set Ω'.

A convenient way to represent the relationship between an *ex ante* expectation (i. e., conditioned on the initial information) and an *ex post* expectation (conditioned on updated information) is that

$$E(\theta \mid \Omega') = E(\theta \mid \Omega) + \varepsilon, \qquad (4)$$

where ε is a forecasting error.

The *ex ante* estimate will be unbiased if $E(\varepsilon) = 0$. Furthermore, the forecasting error ε should be uncorrelated with the expectation of costs conditioned on the information that is available before the rule is enacted. If it were correlated, knowledge of the correlation could be used to derive a better estimate.

If we had a large sample, all of whose values of costs were drawn from the same distribution, and all of whose realizations of conditioning information were drawn from the same distribution, it would be relatively easy to test the hypothesis that ε has zero mean. We could simply compare the averages of *ex ante* and *ex post* costs.

This procedure would be somewhat problematic, in our case, however, as each observation on a pair of *ex ante* and *ex post* cost estimates is drawn from a unique experiment. The procedure of adding up *ex ante* costs estimated from different studies and comparing them with the sum over a corresponding set of *ex post* costs would mix "apples and oranges", and the resultant comparison of differences in means would be unduly influenced by those observations for which costs were highest.

A better procedure would be to specify an empirical version of expression (4):

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[8] The classic example here is the quotient of two normal distributions, which has a Cauchy distribution. It would be impossible to tell from the ratio of *ex ante* to *ex post* estimates if the former were accurate, as the Cauchy distribution has no moments. Of course, it seems unreasonable to suppose that the costs of many regulations could reasonably be defined on a support of $[-\infty, \infty]$.

$$E(\theta_i \mid \Omega_i') = \alpha + \beta E(\theta_i \mid \Omega_i) + \varepsilon_i, \quad (5)$$

where α and β are unknown parameters to be determined, the subscript *i* indexes observations on different prospective regulations, and ε_i is a random disturbance term with mean zero and which is uncorrelated with the *ex post* estimate of costs. The null hypothesis to be tested is, then, that $\alpha = 0$ and $\beta = 1$.

I have estimated equation (5) using as data *ex ante* and *ex post* cost estimates reported in Harrington, *et al*. (2000; specific cost data were found in an earlier working paper, Harrington, *et al*. 1999), MacLeod, *et al*. (2006), and Oosterhuis, *et al*. (2006; this study includes both original case studies conducted by the authors and summaries of eight other case studies in which *ex ante* estimates were developed by Jantzen, *et al*. (1989) and *ex post* estimates reported by RIVM (2001)).

As detailed descriptions of the data from these studies is included with each, I will not repeat such descriptions here. I might, however, note, in passing that I was unable to employ nearly as many data points as might be inferred from the numbers of cases considered in the studies. It is rather surprising when one consults the actual studies that clear, consistent, quantitative statements concerning both *ex ante* and *ex post* costs are more the exception than the rule. Harrington, *et al*., for example, cite 28 cases. I use only seven. The others were eliminated for want of quantitative data (either in Harrington, *et al*. 2000, or the working paper on which it was based, Harrington *et al*., 1999)[9], or because the authors reported only unit-cost estimates which may not be comparable with aggregate estimates (this, incidentally, is why I have not included any cost estimates from Anderson and Sherwood 2002, or Dale, *et al*., 2009). Similarly, it was possible to derive comparable numbers for *ex ante* and *ex post* costs for only three instances in the MacLeod *et al*. (2006) report, and Oosterhuis, *et al*. (2006) proved useful only inasmuch as we adopted figures that it reported from Jantzen, *et al*. (1989) and RIVM (2001). I did not consider studies such as OMB (2005), which compiles estimates from other sources (relying heavily, for example, on Harrington, *et al*. 2000), or Hodges 1999, which reports *industry*, rather than regulators', estimates of costs.

I decided on a sample of 18 regulations (see Table 1). Six are from the United States, one from Canada, eight from the Netherlands, and three from the United Kingdom. Regrettably – and surprisingly – only one US EPA regulation has clear quantitative estimates of both *ex ante* and *ex post* costs corresponding to total (as opposed to unit) effects. Performing the regression indicated in (5) yields the following results:

$$E(\theta_i \mid \Omega_i') = \underset{(0.132)}{-0.092} + \underset{(0.084)}{0.948} E(\theta_i \mid \Omega_i) \quad (6)$$

[9] For example, the authors write of the phase-out of lead from gasoline that "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." While this judgment allowed Harrington *et al*. to classify this rule among those for which *ex ante* costs were estimated with reasonable accuracy, it does not allow me to employ the observation in my quantitative procedures.

$R^2 = 0.889$ (standard errors in parentheses).

In neither specification can I reject the hypothesis that the intercept is zero and slope one, i. e., that *ex ante* estimates of the costs of regulation are unbiased.[10]

It would be foolish to try to make too much of these results. Among other potential problems, it is more reasonable to regard the eighteen before-and-after estimates of costs I have used as a convenience sample than as any sort of random draw from the entire universe of cost estimates. In fact, one might suggest that the fact that I do have good before-and-after estimates for these eighteen rules is evidence that they were more carefully analyzed than were the many other rules that have been mentioned in studies comparing *ex ante* to *ex post* estimates of costs.[11] Moreover, the observation that I cannot reject the hypothesis that *ex ante* cost estimates are biased does not imply that such estimates are "good". There is still considerable variation in the sample, as evidence by the fact that the ratio of ex ante to ex post estimates ranges from 0.207 to 11.2. If nothing else, it would appear that cost estimates can be a long way off, in either direction.

5. Conclusions

Conclusions were foreshadowed in the introduction, so I will only briefly recapitulate them here. The first is that any presumption that regulatory costs are overestimated, and hence that a more liberal interpretation of cost-benefit tests is warranted, is premature. While I am not aware of any commentator who has made this point explicitly, at least with regard to regulator's, as opposed to industry's estimates of costs, it is certainly the subtext of some comments. Again, such evidence as exists does not support such a procedure.

"Such evidence as exists" is, however, sparse. While the authors of existing studies have labored diligently to gather evidence, the evidence remains limited. Moreover, different studies have assembled different data in different ways. While I have tried to compare studies that report similar measures of costs, discrepancies remain between studies as to, e. g., how to include capital investments and variable costs, time periods, discounting, etc. My results can only be considered suggestive at best.

Moreover, as other authors have suggested, conducting retrospective studies of the accuracy of *ex ante* cost estimates remains something of an orphan activity (see, e. g., Hahn and Tetlock 2008). It is understandable that regulators would put a higher priority on predicting the

[10] It might reasonably be suggested that the regression reported in equation (6) will be very inefficient, as we might reasonably expect considerable heteroskedasticity: the costs of very costly rules are likely estimated with considerably higher errors than are less costly ones. I also transformed (6) by weighting by *ex ante* estimates and found again that I could not reject the hypothesis that *ex ante* estimates were unbiased.

[11] Some authors have noted that estimates reported in such studies might not have been chosen at random reasons (see, e. g., Hahn and Tetlock 2008). High-profile regulations, rules for which *ex ante* predictions were spectacularly inaccurate, or instances illustrating economists' favorite hobby horses (e. g., those allowing allowance trading) might all be more likely to be considered.

effects of prospective regulations than they would on evaluating the accuracy of their predictions of regulations that have already been promulgated. It is also understandable that those who have ventured predictions in the past would be reluctant to revisit them: the best possible outcome would be that they would be shown to have done their job competently, while the alternative is that their best efforts would be found lacking. Be that as it may, however, it would certainly be useful to high-level decision makers to know how reliable the information they are receiving is – or at least, how reliable it has been in the past. Ultimately, this information might show *why* different studies have over- or underestimated costs, and whether the prospect for technological innovation is, in fact, underappreciated.

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Nation (for US, Agency in parentheses)	Rule	*Ex ante* cost estimates (millions of US dollars)	*Ex ante* cost estimates (millions of US dollars)	Source
Ontario	Ontario water	58	51	Harrington, *et al*. 2000
US (OSHA)	Vinyl Chloride	1000	253	Harrington, *et al*. 2000
US (OSHA)	Cotton Dust	280	83	Harrington, *et al*. 2000
US (OSHA)	Occupational Lead	224	20	Harrington, *et al*. 2000
US (OSHA)	Formaldehyde	11	6	Harrington, *et al*. 2000
US (EPA)	SO2 Phase I	764	779	Harrington, *et al*. 2000
US (OSHA)	Ethylene oxide	24	25	Harrington, *et al*. 2000
UK	Control of Major Accidents Hazards	155	416	MacLeod, *et al.* 2006
UK	Food Safety (General Food Hygiene/Butchers' Shops)	5	25	MacLeod, *et al.* 2006
England	The Welfare of Farmed Animals	3	3	MacLeod, *et al.* 2006
Netherlands	Acidification	2620	1248	Jantzen 1989
Netherlands	Climate change	617	839	Jantzen 1989
Netherlands	Eutrophication	1471	814	Jantzen 1989
Netherlands	Hazardous Substances	3465	2738	Jantzen 1989
Netherlands	Waste Management	4848	5443	Jantzen 1989
Netherlands	Soil sanitation	914	881	Jantzen 1989
Netherlands	Disturbance	923	763	Jantzen 1989
Netherlands	Other	1939	2140	Jantzen 1989