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Is EPA's Ozone Standard Feasible?

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J O I N T   C E N T E R

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Executive Summary

The Environmental Protection Agency's estimate of the cost of meeting the new health-based ozone standard is likely to underestimate substantially the actual cost. EPA's cost estimates unrealistically assume that pollution control costs are capped at $10,000 per ton. Yet the required emission reductions in some cities exceed total motor vehicle emissions.

By dropping EPA's assumption of constant cost, I show that meeting the standard in 2010 would cost nearly $5 trillion in one city, and $70 billion in seven other cities. These cost estimates exceed EPA's estimates of $10 billion per year by orders of magnitude. I also find that the incremental costs of control are likely to far exceed any estimates of incremental benefits.

The high cost of meeting the ozone standard strongly suggests that it is likely to be infeasible to achieve in several cities. To avoid having EPA set such infeasible standards, Congress should amend the Clean Air Act to require the agency to balance the benefits and costs of regulation.

Is EPA's Ozone Standard Feasible?

Randall Lutter

Environmentalists often contend that statutes should allow or require regulatory agencies to issue rules to protect the environment without regard to the cost of such protection.[1] They have argued this point so successfully that regulatory agencies and courts have interpreted statutory provisions that are silent on the role of cost to prohibit consideration of cost in regulatory decisions. These statutes include the act establishing Superfund,[2] the Clean Water Act, and the Resource Conservation and Recovery Act. Perhaps the most notable such statute is the Clean Air Act, which directs the Environmental Protection Agency (EPA) to set air quality standards to "protect public health" with an "adequate margin of safety".[3] EPA and the courts have interpreted this language to prevent *any* consideration of cost.[4]

The neglect of cost in regulatory decision-making has given some key policy debates an Alice-in-Wonderland quality. In the case of the 1997 air quality standards, EPA Administrator Carol Browner rejected any consideration of cost until their implementation,[5] although there appears to be little flexibility at implementation because the Clean Air Act establishes specific deadlines by which compliance is mandatory.[6] This rejection was particularly important for the ozone standard, which EPA estimated had annual costs billions of dollars greater than likely benefits.[7] The statutory prohibition on considering costs thus provides a legal rationale for a policy position that otherwise would be bizarre.

There is widespread misunderstanding of the cost of EPA's 1997 air quality standards despite the attention to the standards.[8] EPA's estimate of $48 billion per year is

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[1] See, for example, Browner (1997), "Costs of meeting the standards and related factors have never been considered in setting the national ambient air quality standards themselves...I continue to believe that this is entirely appropriate."
[2] The Comprehensive Environmental Response, Compensation and Liability Act of 1980.
[3] See Clean Air Act, Public Law 101-549,1970; 42 United States Code 7409.
[4] See EPA (1997a) for a discussion of earlier court cases. See also *American Trucking v. EPA*, 175 F.3d 1027 (DC Cir 1999). See Lutter and DeMuth (1999) for a discussion of *American Trucking*.
[5] See Browner (1997).
[6] See, however, Melnick (1990).
[7] See EPA (1997b).
[8] See, for example, Wald (1999), Sunstein (1999), and Bentley and Haffner (1998). In May 1999, the U.S. Court of Appeals for the District of Columbia Circuit blocked the standards based in part on a finding that

based on an assumption that emissions reductions amounting to 80 percent of the total cost can be achieved at a constant rate of $10,000 per ton.[9] But this assumption lacks any empirical basis. More importantly, it violates the principle of diminishing returns. Therefore EPA's cost estimates are likely to be too low by an amount that Shogren dubbed the "lost triangle".[10]

Misunderstanding of the cost of the standards results from both the neglect of cost in regulatory decision-making and EPA's campaign to persuade the public that the rules are reasonable. Since the standards are health-based, cost estimates are irrelevant during judicial review, and actual and potential litigants have not examined them. Public commenters did not examine EPA's cost estimates because EPA published estimates of the cost of attaining the standards only *after* the deadline for public comments had passed.[11] Finally, analysts and advocates alike have seen little need to reassess the estimates because EPA's estimates already imply that the standards are the most costly regulatory initiative of the decade.

Such misunderstanding should be expected; independent analysts are often skeptical of agency estimates of the costs and benefits of their regulations.[12] Agency estimates are generally not subject to scientific peer-review or to judicial review. No government body independent of the executive branch reviews agency estimates of regulatory costs and benefits.[13] Moreover, agencies' prospective cost estimates rarely coincide with retrospective estimates of the effects of regulatory actions.[14]

Yet the reliability of agency estimates of regulatory costs (and benefits) is important, because reliable estimates are necessary to satisfy the public's right to know the expected effects of regulatory actions. Agency estimates of regulatory costs and benefits are typically the only official government estimates and thus are the basis of

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they represented an unconstitutional delegation of power. In October it rejected a request for an *en banc* hearing. EPA Administrator Carol Browner has said that she will seek an appeal and the Supreme Court may hear the case. See Lutter and DeMuth (1999).

[9] See EPA (1997b, ES-12 and ES-13). These and other values are in 1990 dollars. Values expressed in 1998 dollars would be about 24 percent higher.

[10] See Shogren (1998). Of course, EPA disagrees. It writes "the $10,000 cost estimate for these reductions is intended to provide ample margin to account for unknown factors associated with future projects, and *may tend to overestimate* the final costs of attainment" (emphasis added), EPA (1997b, p. ES-9).

[11] See EPA (1996a) and (1997b).

[12] See Lave (1996).

[13] See Lutter (1999).

[14] See Harrington, Morgenstern, and Nelson (1999), and Lutter (1999).

recent efforts to satisfy the public's right to know. The Unfunded Mandates Act of 1996 requires regulatory agencies to estimate and report the costs of their regulatory decisions. In addition, Congress has directed the Office of Management and Budget to report on the costs and benefits of federal regulations, and its reports use agency estimates.[15] If unreliable cost estimates misinform the public about the merit of regulatory programs, these reform efforts will be ineffective.[16]

In this paper I reassess the expected costs of EPA's 1997 ozone standard by relaxing EPA's assumption that sufficient emissions reductions will be available at a cost of $10,000 per ton and reinterpreting the cost curves implicit in EPA's analysis.[17] I find that attainment of the standard is infeasible in one city, and that costs in other cities in 2010 are about seven times greater than EPA's national estimates, even after allowing for technological progress. I also show that the cost of meeting the standard is not likely to fall over time—increasing levels of economic activity will dominate cost declines driven by technological progress. Thus, in cities where attainment is feasible but expensive, it may not be sustainable. Finally, I assess a set of emission control measures that is broader than those considered by EPA and includes taxes and fees on motor vehicle use and traffic congestion. I show that such implementation strategies would lower the cost of meeting the ozone standard, but that the cost would still exceed EPA's estimates.

The next section of this paper presents an analysis of EPA's data. This analysis includes illustrations of cost curves for Los Angeles, cost estimates for eight metropolitan areas, and estimates of the rate of change of cost over time. The subsequent section discusses market-based implementation measures. The final section explores broader policy implications.

[15] See Office of Management and Budget (1998). See also Hahn (1999) and Hopkins (1991).

[16] See Urdan (1999), for a discussion of recent legislative efforts to assign to the General Accounting Office responsibility for conducting benefit cost analysis of federal regulations. See also Lutter (1999) for a discussion of the merit of such ideas.

[17] I go beyond Shogren (1998) who did not provide an estimate of the size of the lost triangle, but limit my analysis to ozone. For particulate matter, an assessment of the importance of EPA's assumption that necessary emissions reductions would cost no more than $10,000 / ton is complicated because EPA's analytic approach is different than for ozone and involves other assumptions as well.

Analysis

The single biggest difficulty in estimating cost is the need to extrapolate beyond the range of available data–a problem identical to one encountered in assessing the risk from environmental hazards. In assessing environmental risks, such as those from ozone and particulate matter, toxicologists and epidemiologists typically estimate an association between the risk of disease or injury and exposure to a hazard, *at some level of exposure*. They then extrapolate this association to estimate risk at much lower doses or levels of exposure. Of course, the extrapolation makes such estimates controversial.[18] In estimating the cost of meeting the ozone standard, I relate estimates of cost and emissions reductions for engineering-based control measures identified by EPA. These measures can achieve only a fraction of the emissions reductions needed to attain the standard in cities with serious air quality problems. Estimates of the cost of the standard must therefore involve extrapolations of cost curves well beyond the range of available data. Thus estimates of the cost of the ozone standard are subject to the same concerns about the validity of extrapolation as apply to low-dose risk assessments.[19]

In estimating the cost of meeting EPA's air quality standard, I take for granted all aspects of EPA's analysis with two exceptions. First, I relax its assumption that the cost of reducing emissions is capped at $10,000 per ton. Second, I allow explicitly for technological change and address uncertainties in future technological change by allowing for different rates of decline in marginal abatement cost.

EPA's estimates may be too low because they exclude indirect costs—a deficiency not addressed by this analysis. Indirect costs occur because efforts to remedy environmental problems can exacerbate distortions caused by pre-existing taxes. Economic research by Goulder and others indicates that indirect costs can be a large percentage of direct costs and may exceed them.[20] If estimates of indirect costs were added to the direct costs, the estimated total cost of meeting EPA's standard would be significantly higher than the estimates presented here.

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[18] See, for example, Ames and Gold (1996) and Hendee (1996).

[19] Of course there are other sources of uncertainty. The baseline from which emissions are reduced is uncertain because of uncertainties in future levels of economic activity and in the effectiveness of pending regulations to limit emissions. The emissions corresponding to attainment of the air quality standards are uncertain because the relation between emissions and air quality is relatively poorly understood.

[20] See Goulder, Parry, and Burtraw (1997), and Goulder and Williams (1999).

An Illustration: Los Angeles

I illustrate the analysis using EPA data from Los Angeles, Riverside and Orange counties, the area with perhaps the most severe ozone pollution in the country. Ozone is the product of chemical reactions involving sunlight and two sets of "precursors", volatile organic compounds (VOCs) and nitrogen oxides (NO_x). Since there are different control technologies for each precursor, I present cost information for each separately.[21] (See figures 1 and 2.)

EPA's data include cost and emissions reductions for a set of engineering measures to reduce emissions.[22] If these measures are ranked by their annual cost per ton of emissions reductions, they resemble a cost curve. In figure 1, I present EPA's data on the cost of controlling VOCs and a marginal cost curve fitted to these points. The baseline for the emissions reductions in figure 1 is a scenario for 2010 in which economic growth lifts emissions beyond current levels, but more stringent control measures limit emissions. Emissions reductions are measured in tons per day during the ozone season.

I estimate the marginal cost curve by assuming that the relationship between (the log of) marginal cost and (the log of) emissions reductions is quadratic. The fixed effect regression underlying this curve, presented in table 1, allows the slopes and the intercepts of the marginal cost functions to vary across the different metropolitan areas. As shown in table 1, almost all the coefficients in the cost functions are highly statistically significant and have the expected sign.[23]

The total cost of meeting the new standard is the area under the marginal cost curve between two levels of emissions. The first level corresponds to compliance with the old 1 hour standard that was issued in 1979, and the second level reflects attainment of the 8 hour standard issued in 1997. It is not clear from EPA's analysis that these levels of

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[21] One control measure, a transportation control measure listed as "highway vehicles, gasoline", reduces 1.1 tons per day of VOCs and 2 tons per day of NO_x at a cost of 6.8 million dollars per year. As there is no simple way to incorporate measures with joint products into this analysis, I delete this measure from the scatterplots when estimating the cost functions, but calculate the emission reductions needed to meet the standard after netting out the emissions reductions achieved by this control measure.

[22] The data are in an Excel file Case1i.xls available in the EPA docket.

[23] The data used in the regressions are for a subset of the cities analyzed by EPA. The subset includes all cities for which the cost of meeting the standard is likely to be high. In particular, I select cities if the necessary emissions reductions beyond the identified measures are at least 100 tons per day for VOCs and NO_x combined and the reductions for each pollutant are greater than zero.

emissions correspond to the least-cost way of meeting the standard.[24] In particular, reducing NO_x emissions a little bit more and VOCs emissions a bit less may reduce the total cost of meeting the air quality standard. In the absence of information about such tradeoffs, I use EPA's estimates of the necessary emissions reductions.

Rather than using a similar approach, EPA instead estimated cost by assuming that emissions reductions are available at $10,000 per annual ton per year, or about $4 million per ozone season daily ton. Figure 1 presents a graphical depiction of EPA's cost estimates as a rectangle.[25] The total cost of reducing VOC emissions to meet the 8 hour ozone standard in Los Angeles in 2010, from a baseline of attainment of the 1 hour standard, is about $340 million per year, according to EPA.

For NO_x, two estimates of the marginal cost of reducing emissions appear in figure 2. Curve a is the marginal cost derived from a total cost regression that is cubic in the log of emissions reductions.[26] Curve b, derived as for VOCs, is from the regression that appears in table 1. Interestingly, curve b appears not to fit the most expensive data points. Curve a, which appears to fit the Los Angeles data better than cost curve b, implies cost in 2010 of about $0.1 septillion for Los Angeles. Similar curves, however, do not fit data for other cities as well as the marginal cost functions that I choose to emphasize. EPA estimated the cost of reducing NO_x in Los Angeles to be only $580 million per year, an amount that is much less than the area under either cost curve a or b.

The cost curves presented in figures 1 and 2 do not take into account the technological change expected to occur before 2010—something that is obviously difficult to forecast. Technological change among the identified technologies may be thought of as similar to the technological progress in manufactured goods. Research and development, learning-by-doing and human capital improvements will lower the cost of

[24] See EPA (1997b).

[25] Since EPA did not estimate the costs of attaining the standards for each metropolitan area, I derive EPA's cost estimates from the reductions in tons of emissions per day during the ozone season necessary to attain the 8 hour standard, adjusted to annual tons based on relationships between the daily emissions reductions and the annual emissions reductions of the control measures EPA identified, and EPA's assumed cost of $10,000 per annual ton reduced. Excel File Case1i.xls, provided by EPA, indicates that the ozone season days per year implicit in the emissions estimates is 410 for NO_x and 329 for VOCs.

[26] The regression equation for NO_x emissions controls for Los Angeles is

$$\underset{}{total\ \cos t} = \underset{(16.2)}{311} + \underset{(11.7)}{230\,er} - \underset{(2.82)}{54.6\,er^2} + \underset{(0.225)}{4.36\,er^3}$$

implementing these identified technologies, but the magnitude of such cost declines is hard to anticipate. Estimating the cost of implementing *unidentified* emissions reductions is even harder. When will research regarding these new technologies be completed? When will they be developed, marketed and adopted by industry, or mandated by regulators? What will be their cost and effectiveness when first adopted? There are no easy answers to these questions.

For simplicity, I account here for future technological change by estimating the rate of decline in the cost of emission controls based on the set of new technologies listed by EPA in its regulatory analysis. The arithmetic mean of the average rates of annual cost decline observed among the technologies cited by EPA is 7.7 percent.[27] An annual rate of change of 7.7 percent implies that cost in 2010, thirteen years after EPA's analysis was completed, would be about 37 percent of its 1997 value. This estimate overstates likely technological progress, however, because it reflects cost declines only in successful new technologies. Some new technologies, such as nuclear power generation, are adopted but then turn out to be more costly than originally anticipated. To account for such failures among new technologies I use 5 percent as an average rate of cost decline. In this case cost would equal 52 percent of their original values by 2010. The cost of meeting EPA's ozone standard in Los Angeles in 2010, based on rates of decline in abatement cost of 7.7 percent and 5 percent is $8.1 billion and $11.5 billion respectively.

How great would technological progress need to be in order for EPA's estimates of cost to be correct? The cost of abating emissions would have to fall by 27 percent per year from 1997 to 2010 for EPA's cost estimates to be correct. This is an extraordinarily and implausibly high rate of technological progress.

Estimates for Other Cities

For other cities the cost estimates are about $4700 billion in 2010, assuming that technological progress between 1997 and 2010 will lower cost by approximately half (see table 2.) All but $71 billion of the annual cost occurs in Fresno, California, where EPA estimates that NO_x and VOCs must be cut by more than 60 percent from baseline levels.

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where *er* denotes emissions reductions, both total cost and emissions reductions are transformed into natural logarithms, and the standard errors appear in parentheses.

[27] This estimate reflects only retrospective estimates of cost declines.

But even ignoring the cost in Fresno, the cost estimates for the seven other cities—after netting out improvements due to technological progress—are seven times greater than EPA's cost estimate. For the New York City nonattainment area, the total cost of attaining the 8 hour standard, after technological progress, is $2.9 billion per year. For Washington-Baltimore, however, the expected cost is $7.4 billion per year, and for the San Francisco area the cost is $24 billion per year.

The true range of uncertainty about these cost estimates is quite large. The estimates are fairly sensitive to alternative assumptions about the form of the relationship between cost and emissions reductions, because they necessarily involve large extrapolations beyond the range of available data. Regressions not reported here tend, however, to give similar qualitative conclusions: costs are astronomical in a couple cities and generally many times greater than EPA's estimates.[28]

The broad conclusion—that the standard in some cities is too expensive to be met—is not surprising given that emissions reductions needed to meet it are very large relative to those available using identified measures. Table 3 shows estimates of the necessary emissions reductions, beyond the reductions from controls identified by EPA, as a percent of baseline emissions. Six cities require very large emissions reductions beyond those achieved by the identified measures: the reductions amount to more than 40 percent of baseline emissions. In addition, all eight cities require emissions reductions at least four times greater than the reductions from measures identified by EPA. For two cities, necessary reductions are more than ten times greater than those identified by EPA.

Changes Over Time

EPA suggests that technological progress may lower compliance cost over time.[29] But economic growth increases the emissions reductions necessary to meet the standard. Identifying the net change in cost over time is thus an unresolved empirical question.

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[28] Total cost functions that are quadratic in (the log of) emissions reductions implied that annual costs for two cities exceeded $1 trillion per year, for another city the cost exceeded $350 billion. The total cost for the remaining five cities I assessed was $19 billion per year. These estimates assume no technical progress. The regressions, however, have more coefficients that are statistically insignificant than the marginal cost functions presented here.

[29] See EPA (1997a).

The rate of change of total cost, as shown in the appendix, is a weighted average of the rate of change of the cost of controlling VOCs and the rate of change of the cost of controlling NO_x, where the weights are the share of total cost associated with each pollutant. The rate of change of the total cost, TC, of controlling each pollutant, g_{TC}, can in turn be estimated as

$$(1) \qquad g_{TC} \; = \; - \, r \; + \, g_L \left(\frac{e_R \; TC(R)}{(R \;\; TC)/L} \; - \; \frac{e_B \; TC(B)}{(B \, TC)/L} \right)$$

where D is the annual rate of decline in cost as a result of technological progress, g_L is the growth rate of laissez-faire emissions, and g_R and g_B are the elasticities of total cost with respect to emissions reductions evaluated at emissions reductions sufficient to meet the new standard, R, and to meet the old standard, B, respectively. The variables TC(R) and TC(B) are the total costs of achieving emissions reductions R and B from a baseline of zero reductions, and TC is the total cost of meeting the standard from a baseline of attainment of the old standard.

What do we know about the values of the parameters that determine the rate of growth of total cost? As described above, a good estimate of the rate of decline in cost is 5 percent per year. The rate of growth in uncontrolled emissions, g_L, is hard to estimate empirically in a regulated world but it is related to the rate of growth in real economic activity. Over the period from 1980 to 1997, GDP has grown at about 2.7 percent annually.[30] About a third of emissions comes, however, from the use of motor vehicles, which grows at the rate of about 2 percent per year.[31] Thus a good estimate of g_L is a weighted average of motor vehicle and other emissions, where the weights reflect the shares of total emissions. This weighted average is about 2.5 percent.

The variables g_B and g_R can be derived from the cost curves presented in table 1.[32] For Los Angeles, the elasticities for NO_x are 4.4, while for VOCs, g_B and g_R are 3.3 and 3.2 respectively.

[30] See Council of Economic Advisers (1999, Table B.2).
[31] See EPA (1997b).
[32] The use of this baseline, which may differ from the conceptually correct baseline, imparts no clear bias to the results. Equation (1) uses a laissez-faire baseline, while the cost curves presented in figures 1a and 1b use a baseline of full-compliance with technology based requirements of the Clean Air Act. The uncertainty associated with identifying laissez-faire emissions in a regulated world makes the conceptually correct baseline unworkable.

Using these estimates, and the values of B, R, and L implicit in figures 1 and 2, implies that the cost of controlling NOx (to the level of the new ozone standard) grows 15 percent per year, while the cost of meeting the VOC standard (to the level of the new ozone standard) grows at 3 percent per year. [33] The cost of meeting the ozone standard in Los Angeles therefore will grow at a weighted average of these two estimates, or 12 percent per year, after 2010.

The rate of technological progress will have to be 20 percent per year in order for the cost of meeting the standard in Los Angeles to fall after 2010, based on the preceding estimates and equation (1). Such technological progress appears extremely unlikely.

Rapid growth in the cost of meeting the ozone standard does not imply that the present value cost of attaining the standard in perpetuity is infinite. That would be the case if annual cost continued to rise by more than the discount rate. But rising control cost would eventually curtail economic growth.[34] Indeed, rising costs suggest that cities that are able to attain the standard in 2010 may later find that attainment is too costly to be feasible.

Improved Implementation Strategies

The preceding cost estimates, like EPA's own estimates, ignore control measures based on behavioral changes—such as gasoline taxes and carpool programs—which some analysts believe can substantially reduce the cost of meeting EPA's air quality standard.[35] In fact, while such strategies may be much more efficient than some of the control measures analyzed above, they do not alter the basic conclusions of this paper.

A study sponsored by the state of California reports that emissions control measures based on relatively small behavioral changes can be a cost-effective means of reducing local air pollutants (see table 4). Congestion pricing, for example, lowers congestion and greenhouse gas emissions in addition to reducing local air pollution, without an obvious effect on automobile accidents.[36] Since traffic delays are very costly,

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[33] For NO_x, B and L and R are 318, 1048 and 460 respectively. For VOCs, the values are 526, 1064, and 628 respectively.
[34] See Aghion and Howitt (1998).
[35] See EPA (1999).
[36] With less congestion average vehicle speeds rise, but it is unclear whether this would increase or decrease the social cost of vehicle accidents.

a reduction in them would offer large benefits that would likely offset other costs of such policies.[37]

But the low-cost emissions reductions resulting from such innovative implementation strategies are small compared with the reductions needed to attain the ozone standard. The California report indicates that congestion fees above the levels in table 4 might not be economically justified.[38] A $0.50 per gallon gasoline tax would achieve only a 4 percent reduction in NO_x emissions from motor vehicles; but even with a tax of $2.00 per gallon the reduction in motor vehicle emissions is only 12 percent.[39]

In fact, the complete *elimination* of emissions from motor vehicles appears insufficient to attain the standard in 2010 in some places. In Los Angeles, for example, the necessary emissions cuts beyond the measures identified by EPA are 33 percent for VOCs, but only 20 percent of VOCs come from motor vehicles.[40] In San Francisco, the NO_x emissions deficits is 45 percent, but motor vehicles contribute only 43 percent of baseline NO_x emissions.[41]

Conclusion

EPA's estimate of the cost of its ozone standard is much too low. In one city the cost is more than a trillion dollars per year while in seven others the costs total $70 billion per year, or about seven times EPA's estimate. Attainment of the standard appears infeasible by 2010.

Attainment costs are likely to rise in years beyond 2010. Costs will rise because progress in new control technologies will be outweighed by increases in baseline emissions resulting from economic growth. Thus attainment of the ozone standard may later become infeasible in cities where meeting it in 2010 is simply very expensive.

The basic conclusion that the standard is infeasible is insensitive to changes in analytic methods. Of course, cost estimates based on extrapolations far beyond the range

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[37] See Edlin (1999) and Calfee and Winston (1998).
[38] See the California Air Resources Board (1996, Table 7.6).
[39] Ibid, Table 7.8.
[40] See California Air Resources Board (1999). Emissions projections for 2010 from CARB are not identical to EPA's 2010 emissions forecasts. Thus CARB's estimates of the percent of total emissions that come from motor vehicles may be different than EPA's estimates; however, EPA's estimates of emissions from different sources are not publicly available.
[41] Ibid.

of available data are very uncertain. But in two cities attainment of the standard will require emissions reductions more than ten times greater than can be achieved by the emission control measures identified by EPA. In addition, the complete elimination of motor vehicle emissions would not ensure attainment of the standard in some cities.

Realistically, costs will never reach the trillions or even hundreds of billions of dollars per year implied by this analysis. Instead the managers of EPA's clean air programs and representatives of States will find new flexibility to avoid attainment of the ozone standard. For example, under the Clean Air Act, the State of California has responsibility for developing State implementation plans that EPA approves and for enforcing emissions limits on polluters that contribute to violations of air quality standards. If the annual cost for a metropolitan area indeed reached the tens of billions or more, affected States would simply get extensions and waivers from EPA, Congress and the courts.

Nevertheless, efforts to attain the ozone standard can still lead to costs that are excessive relative to the health and environmental benefits. EPA gave an upper bound estimate of the national benefits of the ozone rule of $8.5 billion per year,[42] but estimates of benefits consistent with the health effects estimated in the risk assessment blessed by EPA's Clean Air Scientific Advisory Council are hundreds of millions of dollars at best.[43] These benefits estimates imply that a very generous upper bound for the benefits of controlling ozone is $10,000 per ton, and a more plausible value is a very small fraction of this estimate.[44] The upward slope to the marginal cost curves in figures 1 and 2 indicates that the last increment of emissions controls to reduce ozone is likely to have costs hundreds or thousands of times greater than any estimate of projected benefits.

With respect to regulatory issues more broadly, the ability of EPA to present erroneous estimates of the cost of a rule as important as its ozone standard should shed light on the merit of some regulatory reform initiatives that are popular in Washington. Initiatives that seek to increase the importance of agencies' estimates of the cost of their

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[42] See EPA (1997b, ES-16).
[43] See EPA (1996a).
[44] See Lutter and Wolz (1997) and Lutter and DeMuth (1999) for an argument that reductions in ozone increase human exposure to harmful ultraviolet radiation by so much that the expected health improvements may be nil.

own regulations, without first ensuring the reliability of such estimates, can contribute to the public's misperceptions.

Finally, this analysis indicates a new need for cost to be considered in setting air quality standards. After all, adopting standards more stringent than is feasible does not improve children's health or the environment. Such standards do not provide health benefits any greater than less stringent ones, and the existence of infeasible mandatory standards may contribute to distrust of governmental institutions. In addition, there is little sense in setting standards that would cost many times more than the value of the benefits. To ensure a frank discussion of the tradeoffs implicit in major policy decisions, Congress should amend the Clean Air Act to direct EPA to consider costs in setting air quality standards. In particular, it should direct Congress to balance costs and benefits in controlling air pollution.

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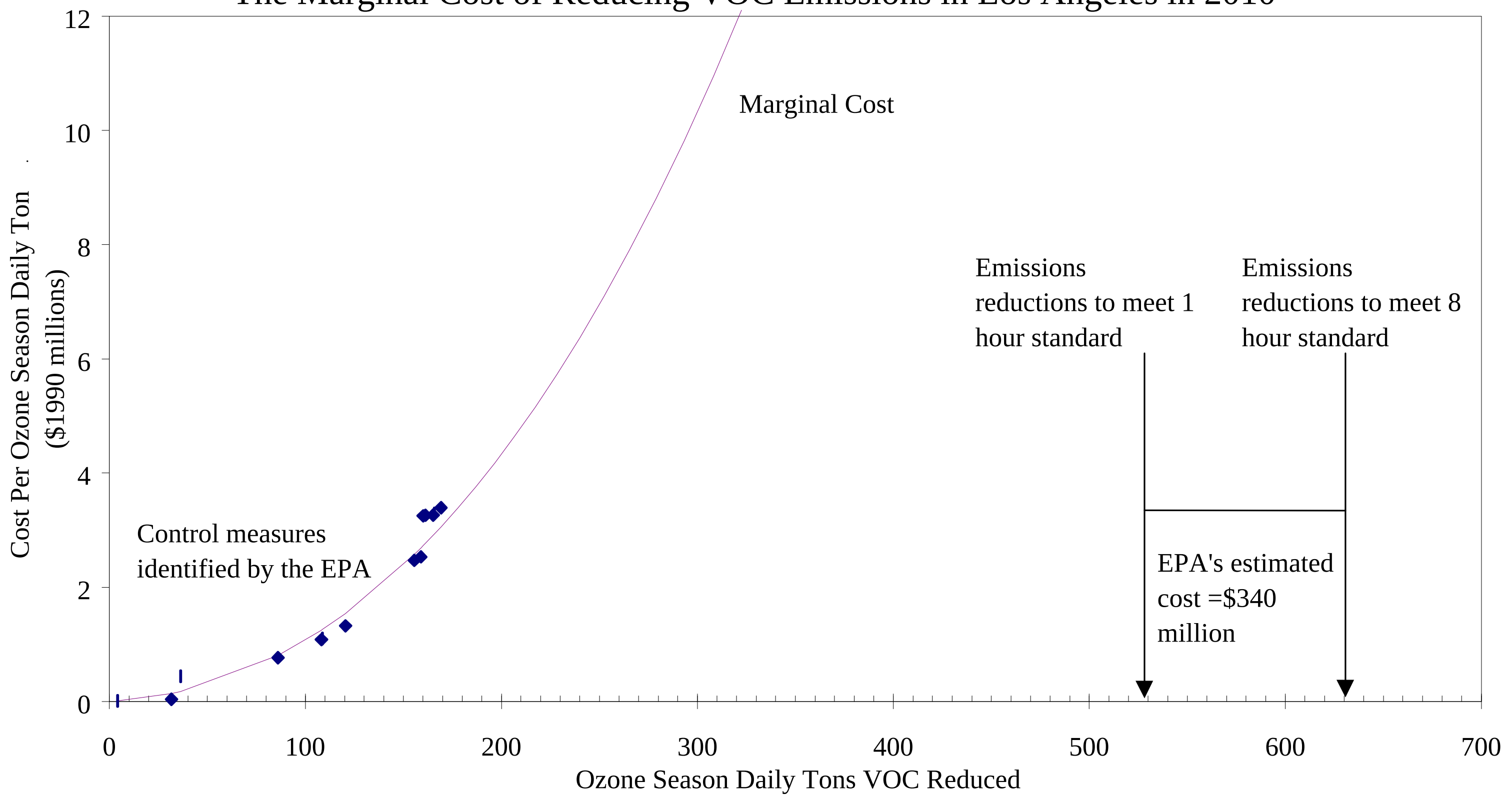
Figure 1

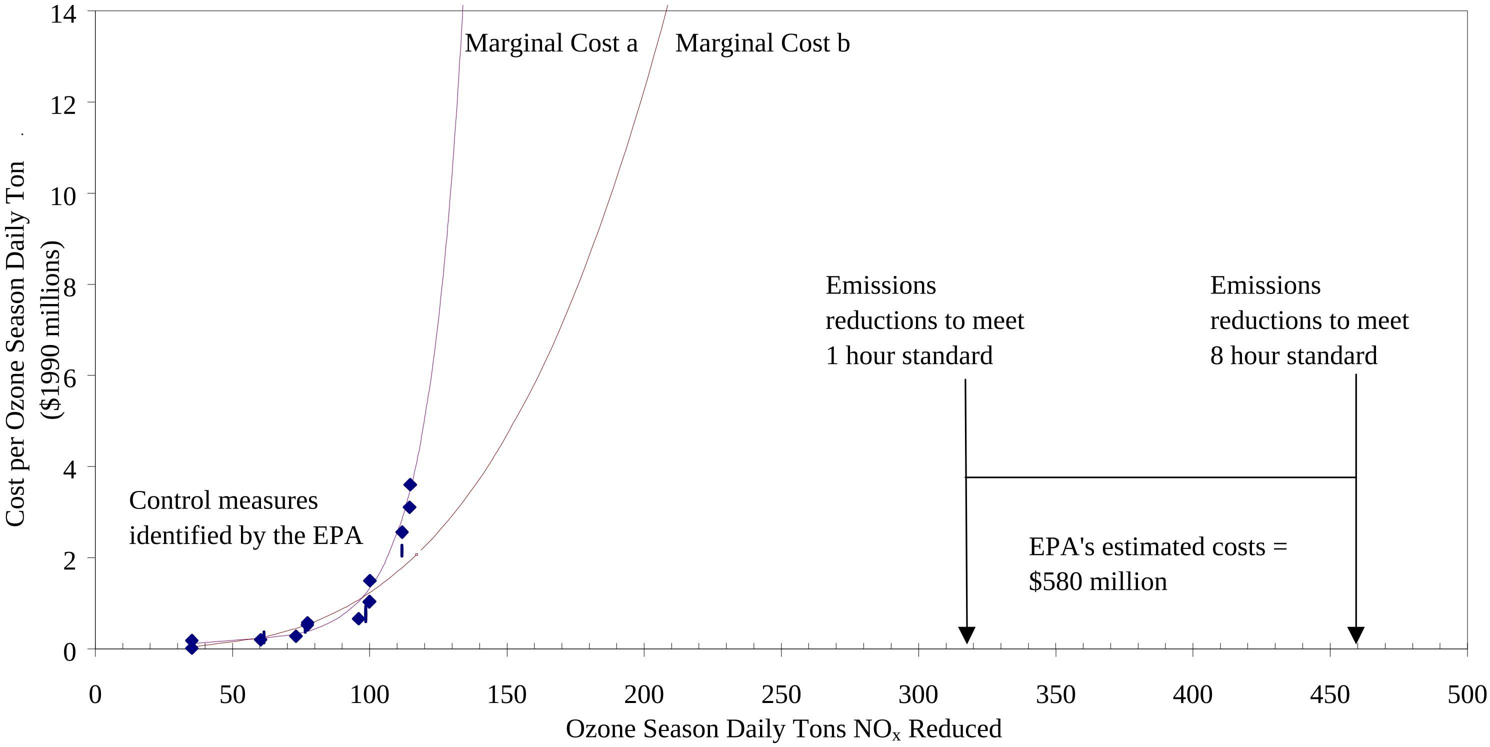
The Marginal Cost of Reducing VOC Emissions in Los Angeles in 2010



Note: The scatterplot excludes controls which reduce both NOx and VOCs and controls which have zero cost according to the EPA. The area described as Los Angeles includes Riverside, Orange and Los Angeles Counties. Emissions reductions are from EPA's baseline of 1054 tons per day. A cost per daily ton of $4 million is equivalent to a cost per annual ton of about $10,000. The benefits of controlling ozone are much less than $4 million per daily ton.

Figure 2

The Marginal Cost of Reducing NO_x Emissions in Los Angeles in 2010



Note: The scatterplot excludes controls which reduce both NO_x and VOCs and controls which have zero cost according to the EPA. The area described as Los Angeles includes Riverside, Orange and Los Angeles counties. Emissions reductions are from EPA's baseline of 1048 tons per day. A cost per daily ton of $4 million is equivalent to a cost per annual ton of about $10,000. The benefits of controlling ozone are much less than $4 million per daily ton.

Table 1
Marginal Cost Regressions for Eight Metropolitan Areas

Variables		Volatile Organic Compounds	Nitrogen Oxides
Square of Emissions Reductions		0.116 (.0432)	.0651 (.0257)
Bakersfield, CA	Intercept	10.6 (.338)	-15.0 (4.98)
	Emissions Reductions	1.35 (.169)	7.79 (1.41)
Fresno/Visalia-Tulare, CA	Intercept	10.6 (.336)	.716 (2.89)
	Emissions Reductions	1.01 (.175)	5.38 (1.28)
Los Angeles-Riverside-Orange	Intercept	7.43 (.829)	.362 (2.03)
	Emissions Reductions	.865 (.336)	2.67 (.498)
New York City-New Jersey-Long Island	Intercept	7.98 (.799)	12.5 (293)
	Emissions Reductions	.406 (.362)	.264 (.0734)
Philadelphia-Wilmington-Atlantic City	Intercept	8.39 (.503)	12.9 (.329)
	Emissions Reductions	.713 (.269)	.354 (.757)
Sacramento-Yolo, CA	Intercept	10.4 (.332)	14.0 (.364)
	Emissions Reductions	1.38 (.189)	1.06 (.208)
San Francisco/Modesto/Stockton-Lodi	Intercept	9.13 (.486)	4.48 (1.52)
	Emissions Reductions	.827 (.265)	2.41 (.468)
Washington-Baltimore	Intercept	8.14 (.575)	12.7 (.279)
	Emissions Reductions	.855 (.291)	.697 (.153)
R^2		0.9984	0.9979
Number of Observations		121	101

Note: The table presents coefficients and standard errors in parentheses. Control measures that reduce both VOC and NO_x, and measures with zero cost are excluded from the regressions. All variables are in natural logarithms.

Table 2
Costs of Meeting the Ozone Standard in Selected Metropolitan Areas in 2010
Billions of 1990 Dollars

Annual Technological Progress	5 Percent			7.7 Percent
Area	Cost of Meeting VOC Target	Cost of Meeting NO_x Target	Total Cost of Meeting the 8 Hour Ozone Standard	Total Cost of Meeting the 8 Hour Ozone Standard
Bakersfield, CA	5.3	15	20	14
Fresno-Visalia-Tulare, CA	1.6	4700	4700	3300
Los Angeles-Riverside-Orange	2.4	9.1	12	8.1
New York-New Jersey-Long Island	0.97	1.9	2.9	2.0
Philadelphia-Wilmington-Atlantic City	0.68	0.69	1.4	0.96
Sacramento-Yolo, CA	0.71	2.8	3.5	2.5
San Francisco-Modesto-Stockton-Lodi	1.3	23	24	17
Washington-Baltimore	2.2	5.2	7.4	52
Total Excluding Fresno	14	57	69	50
Total	15	4700	4700	3300

Note: These cities are all those in EPA's data set with combined VOC and NO_x deficits greater than 100 tons per day and non-zero deficits for each pollutant.

Table 3
Meeting EPA's Ozone Standard Requires Very Large Emissions Cuts

Selected Cities	Reductions in 2010 to Meet the 8 Hour Standard Beyond the Identified Measures / Baseline Emissions (percent)		Reductions in 2010 to Meet the 8 Hour Standard / Reductions from Identified Measures	
	VOCs	NO_x	VOCs	NO_x
Bakersfield, CA	59	32	13	2.3
Fresno-Visalia-Tulare, CA	61	62	6.6	8.8
Los Angeles-Riverside-Orange	43	33	3.7	3.9
New York-New Jersey-Long Island	32	39	2.6	9.4
Philadelphia-Wilmington-Atlantic City	26	31	2.6	4.8
Sacramento-Yolo, CA	37	51	4.3	31
San Francisco-Modesto-Stockton-Lodi	28	45	3.1	7.1
Washington-Baltimore	41	39	3.3	8.8

Table 4
Alternative Emissions Control Measures in 2010
May Achieve Limited Emissions Reductions Cost-Effectively

Type of control measure	Tax rate	Metropolis	Other Benefits (percent reductions)				Previously Implemented?	Annual Government Revenue (millions)
			Traffic Delays	Emissions				
				Carbon	VOC	NO_x		
Congestion pricing	19 ¢ per mile	LA area	32	9.6	8.1	3.6	Not in U.S.	$7300
	13 ¢ per mile	SF Bay area	27	8.3	6.9	3.2		$2300
Minimum single driver employee parking fees	$1.00 /day	LA area	2.7	1.0	.8	.7	Not in U.S.	$1400
		SF Bay area	2.9	1.1	1.0	.9		$500
Gasoline tax	$0.50 / gallon	LA area	9.5	9.3	4.1	3.8	Yes	$3700
		SF Bay area	8.5	8.8	3.5	3.3		$1300
Mileage fee	2 ¢/ mile	LA area	11	5.2	4.2	3.9	Not in U.S.	$3100
		SF Bay area	9.0	4.1	3.8	3.6		$1100

Source: California Environmental Protection Agency, Air Resources Board, 1996. Note SF Bay area refers to the San Francisco Bay area and LA area refers to the Los Angeles area.

Appendix

Total costs can be written as

(1) $$TC = \int_{B(t)}^{R(t)} e^{-rt} MC(r)\, dr$$

where B(t) is the baseline emissions reductions, that is those that would occur in the absence of the air quality standards; t is an index for time, R(t) represents the emissions reductions necessary to meet the standard; $e^{-\rho t}$ is a factor accounting for cost declines related to technological progress assumed to occur at annual rate ρ; MC is the marginal cost of emissions reductions; and r indexes the amount of reductions. Applying Leibnitz's rule implies

(2) $$\partial TC / \partial t = -rTC + e^{-rt} MC(R)R' - e^{-rt} MC(B)B'$$

Using g_x to denote the growth rate of a variable x, (2) implies

(3) $$g_{TC} \equiv \frac{\partial TC}{\partial t}\frac{1}{TC} = -r + e^{-rt}\ MC(R)R'/TC - e^{-rt}\ MC(B)B'/TC$$

Given that R and B rise at constant rates, (3) simplifies to

(4) $$g_{TC} = -r + e_R g_R \frac{TC(R)}{TC} - e_B g_B \frac{TC(B)}{TC}$$

where g_R and g_B are the elasticities of total cost with respect to emissions reductions evaluated at emissions reductions R and B respectively, and TC(R) and TC(B) are the total costs of achieving emissions reductions R and B from a baseline of zero reductions. Note that emissions reductions B and R both grow over time because of growth in emissions under a laissez-faire policy. In fact, if laissez-faire emissions are L(t), then B' = R' = L'.

Since $g_R(R/L)=g_B(B/L)=g_L$, it follows that

(5) $$g_{TC} = -r + g_L \left(\frac{e_R\ L\ TC(R)}{R\ TC} - \frac{e_B\ L\ TC(B)}{B\ TC}\right)$$

Equation (5) is applicable to a cost curve for a single pollutant. Since both NO_x and VOCs contribute to ozone, I develop here an analogous expression applicable when there are two cost curves. Note that the total cost of meeting the ozone standard can be expressed as the sum of the costs of reducing VOCs and NO_x :

(6) $$TC = C_{VOCs} + C_{NOx}$$

Differentiating gives

(7) $$\frac{\partial TC}{\partial t} = \frac{\partial C_{VOCs}}{\partial t} + \frac{\partial C_{NOx}}{\partial t}$$

or

(8) $$g_{TC} = g_{CVOC} \frac{C_{VOCs}}{TC} + g_{CNOx} \frac{C_{NOx}}{TC}.$$

Thus, the growth rate for total cost is a weighted average of the growth rates for the cost of attaining the VOC target and the cost of attaining the NO_x target, where the weights are the shares of total cost attributable to VOCs and NO_x respectively.