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The *Net* Benefits of Incentive-Based Regulation: A Case Study of Environmental Standard Setting

By WALLACE E. OATES, PAUL R. PORTNEY, AND ALBERT M. MCGARTLAND*

Economists interested in environmental, safety, and health regulation have long argued that decentralized, incentive-based (or IB) policies are more efficient than centralized, command-and-control (or CAC) approaches (see Charles Schultze, 1977, for instance). These arguments generally have been based on the assumption that IB policies will accomplish the same goals as their CAC counterparts, but at less cost to society.

However, some of those touting IB policies have overlooked an important point: environmental, workplace, or even product-safety standards typically take the form of maximum permissible concentrations of harmful substances, so that compliance only requires that all monitoring points or samples register readings below these critical levels. For this reason, IB policies typically assign a shadow price of zero to improvements that exceed the standard(s), while more crude CAC policies generally result in "overcontrol" beyond the standards. If there is no value to this overcontrol, CAC policies will not improve at all on IB approaches and will indeed be more expensive. If, however, reduced concentrations below the level of the standards bring with them further improvements in health or the environment, CAC approaches will produce greater benefits than IB approaches. Thus, a fair comparison between the two necessitates that any additional benefits associated with CAC policies be offset against the cost advantages enjoyed by their IB counterparts.

Although this possibility has been recognized by others (Scott Atkinson and T. H. Tietenberg, 1982, for instance), it is little appreciated and its empirical significance has never been ascertained. That is our purpose here. We do so by developing data on the costs and benefits of controlling a common air pollutant, total suspended particulates (or TSP), in Baltimore. By comparing the TSP levels likely under both IB and CAC approaches, we are able to estimate the marginal costs and benefits associated with a variety of alternative air quality standards which take the form of maximum permissible concentrations. This in turn allows us to determine the *net* benefits arising from the two kinds of regimes.

In the next section we present a simple conceptual framework for our analysis. Section II describes the estimation of the costs and benefits of our hypothesized air pollution controls in Baltimore. Section III presents our somewhat surprising findings, and Section IV discusses those findings and their potential significance for regulation in the "real world."

I. The Conceptual Framework

Before turning to our Baltimore data, it will be helpful to set the problem in a more general framework. Suppose that we have a specific "region"—it could be an air shed, a system of waterways, or even the ambient environment in a large factory—in which there are m sources of pollution, each of which is fixed in location. Environmental

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quality is defined in terms of pollutant concentrations at each of n "receptor points" in the region. We can thus measure environmental quality by a vector $Q=(q_1, q_2, \ldots, q_n)$ whose elements indicate the concentration of the pollutant at each of the receptors. This, incidentally, makes one important, if obvious, point: the "level" of environmental quality is actually a set of pollutant concentrations at different points in the region—it is not (for most pollutants) simply a single level of pollution.

The dispersion of emissions from the m sources in the region is described by an $m \times n$ matrix of unit diffusion (or transfer) coefficients:

$$D = \begin{matrix} & \vdots & \\ \ldots & d_{ij} & \ldots, \\ & \vdots & \end{matrix}$$

where d_{ij} indicates the increase in pollutant concentration at receptor j from an additional unit of emissions of the pollutant by source i. If we denote by e_i the level of emissions by source i, we can then describe the pattern of waste emissions in the region by the vector $E=(e_1, e_2, \ldots, e_m)$. The levels of pollution at the various receptor points can then be determined by mapping the vector of emissions through the diffusion matrix:

$$ED = Q.$$

Finally, we introduce the abatement cost function: $C_i(e_i)$ is the cost to source i of holding its emissions to e_i.

Let us suppose that some standard for environmental (or workplace) quality has been set—we take it for now as predetermined. The standard takes the form of a maximum permissible level of pollutant concentration at any receptor point in the region. There are various regulatory strategies that an environmental agency might pursue to comply with the standard. Following a "command-and-control" (CAC) approach, the agency might specify abatement technologies for the sources. Suppose, as is common practice, that it required all similar sources to adopt the same control procedures and tightened up these procedures until the standard was everywhere satisfied. Such a control program would result in a specific vector of emissions from sources—call it E_c. And this vector would map through the diffusion matrix into a vector Q_c of pollutant concentrations.

Note that in virtually all cases the standard will be binding at only one or a few receptors. Most receptors will have pollutant concentrations below that required by the standard so that environmental quality at most points in the air shed, waterway, or workplace will exceed that prescribed by the standards. *It is also clear that the resulting vector of environmental quality (and the associated levels of damages and control costs) depends on the specific regulatory program adopted by the agency.*

Suppose instead that the environmental agency pursues an IB strategy. By this we mean that it seeks that vector of emissions (E_1) that can attain the standard at the minimum aggregate abatement cost:

$$\begin{aligned} &\text{Min}\, \Sigma C(e_i) \\ &\text{s.t.} \quad ED \leq Q^* \\ &\qquad E \geq 0, \end{aligned}$$

where Q^* is the upper bound on allowable pollutant concentrations. There are various ways this might be done, including the use of effluent fees or transferable discharge permits. Such a program will, by definition, achieve the standard at a cost less than (or equal to) our CAC program. And this will involve a different vector of emissions. In general (as existing studies show), the IB vector will entail higher levels of emissions and higher levels of pollutant concentrations at nonbinding receptor points than will the CAC solution. This is not surprising, since the cost-minimization procedure assigns a zero shadow price to any additions to pollutant concentrations so long as the standard is not exceeded. In its search to reduce abatement costs, the IB approach effectively makes use of any "excess" environmental capacity to allow increased emissions. *Thus, for any given Q^*, we expect in general to find* *levels of emissions, concentrations, and damages that are higher under the IB solution than under the CAC outcome.*

The levels of both benefits and control costs associated with a particular standard will, in consequence, tend to be higher under a CAC than under an IB regime. Just how the levels of *net* benefits and the optimal standard will compare under these approaches is not something we can determine a priori; it is an empirical matter. To get a sense of the magnitudes involved, we investigate in the succeeding sections the benefit and cost functions for a specific air pollutant in the Baltimore region.

II. Estimating Benefits and Costs

To estimate the marginal costs of TSP control under the two regimes, we used a model developed by McGartland (1983, 1984) which reflects the technological control possibilities, associated particulate reduction efficiencies, and costs for about 400 actual sources in Baltimore. The marginal abatement cost function under the IB approach reflects, for each possible standard considered, the least-cost combination of control options across all particulate sources that ensures attainment at all receptors. To estimate marginal costs for the CAC regime, we adopted the basic spirit of the regulatory strategy used in Baltimore. First, all sources were categorized and similar sources grouped together—for instance, industrial coal-fired boilers, grain shipping facilities, etc. Then, marginal costs for additional control were estimated for each source *category*. Finally, when additional controls were required to reduce particulate levels, the source *category* with the lowest cost-per-ton was targeted for further regulation; all sources within that category were required to adopt the same technology regardless of their individual costs or location.

To estimate the marginal benefits associated with alternative standards, we first assigned the 1980 population of the Baltimore metropolitan area to one of the 23 receptors in the area using the geographic coordinates of each census tract and each receptor. This gave us an "exposed population" by receptor ranging from as few as 3,800 people assigned to one receptor to more than 180,000 at another.

Given these exposures, we calculated marginal benefits from successively tighter TSP standards for four different categories: reduced premature mortality, reduced morbidity, reduced soiling damages to households, and improved visibility. For each category, the changes in TSP levels that would accompany successively tighter standards were first translated into physical improvements (fewer sick days, fewer "statistical" lives lost, reduced soiling, and increased visibility). To do so, we relied primarily on the peer-reviewed dose-response studies actually used by the EPA in setting the national air quality standard for particulates. We then monetized these physical improvements using recent studies on the valuation of premature mortality, morbidity, soiling, and visibility.[1] While we have made what we feel are the best estimates possible for marginal benefits and costs, the real value of the analysis lies in the comparisons between the IB and CAC approaches. Such comparisons are more important and more legitimate than inferences about the actual levels of benefits and costs.

To summarize, given a hypothetical change in the TSP standard for Baltimore, the cost model is used to determine how that change will be accomplished technologically under both the CAC and IB approaches. The model not only determines the pattern of controls, emissions reductions, and associated costs under each regime, but also produces a vector of ambient TSP levels at each of the 23 receptors. By comparing this vector with the preexisting one, we can determine the change in air quality at each receptor. Using the mortality, morbidity, soiling, and visibility

[1] We will provide upon request a detailed description of the methods used to calculate the benefit functions. Briefly, the mortality and morbidity benefit estimates are based on cross-section and time-series epidemiological studies of the effects of particulate matter on health coupled with valuations of $2 million per life "saved," $100 per lost work day, and $25 for each restricted activity day. Soiling and visibility benefits are estimated in an analogous way.

"dose-response" functions, we translate the physical changes in air quality into welfare improvements and, simultaneously, value them to arrive at estimates of marginal benefits. That is the process behind the empirical results presented below.

III. The Findings

We report in Table 1 and depict in Figures 1 and 2 our basic results. As we move from left to right along the horizontal axes in the figures, we encounter successively more stringent *standards* as indicated by lower permissible maximum concentrations of TSP. Consider, for example, a TSP standard of 100 $\mu g/m^3$ under the IB case. We see from Table 1 that the marginal control costs of moving from a standard of 105 $\mu g/m^3$ to the more stringent standard of 100 $\mu g/m^3$ are \$1.82 million, while the associated marginal benefits are \$8.53 million. These values appear in Figure 1 as points on the MC and MB curves at a TSP standard of 100.[2]

A cursory examination of the table and the accompanying figures suggests, first, that were we to select an "optimum" standard under each system by equating marginal benefits and costs, the IB approach would give us a more stringent standard than the CAC regime. From Table 1, we see that the "optimum" standard under the IB case is 90 $\mu g/m^3$, while for the CAC case this standard is only 100 $\mu g/m^3$.[3] This result appears to confirm a point that environmental economists have long argued: the adoption of less costly control techniques should make it possible to attain higher levels of environmental quality.

This inference, however, is misleading. The source of the confusion is the natural inclination to associate air quality *standards* with air quality *levels*. But as we have seen, these are not the same thing. We cannot emphasize this distinction enough: an air quality standard maps into a vector of pollutant concentrations and the mapping itself depends, as we have seen, upon the regulatory regime. While it is true for our Baltimore case that the IB "optimum" would lead us to select the more stringent *standard* for air quality, it does not necessarily follow that this would actually result in better air quality throughout the area. Standards do not provide an unambiguous measure of air quality; they are ceilings on permissible levels of pollutant concentrations—most receptors will have concentrations well below the standard. *Thus, the same standard on the horizontal axis in our figures will produce a different vector of air quality under our two regulatory systems.*

To provide a better sense of these differences, we present in Table 2 estimated TSP concentrations for the various standards for a representative sample of our 23 Baltimore

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[2] The marginal benefit and abatement cost curves are reasonably well behaved for the least-cost case in Figure 1. Marginal benefits remain roughly constant over most of the relevant range with some tendency to tail off after a standard of 85 $\mu g/m^3$ is achieved. The relative constancy of marginal benefits results primarily from the fact that the dose-response functions that we use (based on EPA documents) are linear over the range of air quality standards that we consider. The occasional "ups and downs" in the MB curve reflect the differing degree to which individual receptors are controlled as we move to successively more stringent standards.

Marginal abatement costs remain low and well below marginal benefits for less stringent standards, but begin to rise rapidly after a standard of 90 $\mu g/m^3$ is reached. The functions are not so well behaved for the CAC case in Figure 2. In particular, the marginal cost curve exhibits a large "hump" around a standard of 90 $\mu g/m^3$. This hump has its source partly in our rule for regulatory behavior. It turns out that to go from a standard of 95 $\mu g/m^3$ to 90 $\mu g/m^3$ requires the adoption of some additional and rather costly control measures by a large number of sources; our CAC rule necessitates that these measures be applied to a whole class of polluting sources (irrespective of location), resulting in a sharp increase in control costs.

[3] It is interesting that the "optimum" standard for Baltimore for the IB case is quite close to the EPA primary standard for TSP concentrations of about 85 $\mu g/m^3$. (With a standard deviation of roughly 1.5, the EPA primary standard of 75 $\mu g/m^3$ expressed as a geometric mean translates roughly into a standard of 85 $\mu g/m^3$ as an arithmetic mean). As we indicated earlier, we should not make too much of this, for there is considerable uncertainty surrounding the estimates we have used for the benefit and cost functions. What is of more interest is the comparison between the IB and CAC cases.

TABLE 1—MARGINAL CONTROL COSTS (MC) AND MARGINAL BENEFITS (MB) UNDER THE INCENTIVE-BASED AND CAC SYSTEMS (IN MILLIONS OF 1980 DOLLARS)

	Incentive-Based Case		
Standard	MC	MB	(MB-MC)
115	1.36	7.25	5.89
110	1.90	12.94	11.04
105	2.63	9.09	6.46
100	1.82	8.53	6.71
95	4.60	13.22	8.62
90	8.66	15.14	6.48
85	20.98	16.37	−4.61
83	35.23	3.88	−31.35
	Command & Control Case		
Standard	MC	MB	(MB-MC)
115	0.50	2.18	1.68
110	2.45	10.52	8.07
105	3.32	9.69	6.37
100	9.14	11.48	2.34
95	15.06	7.51	−7.55
90	54.67	10.00	−44.67
85	16.00	6.49	−9.51
83	9.95	1.19	−8.76

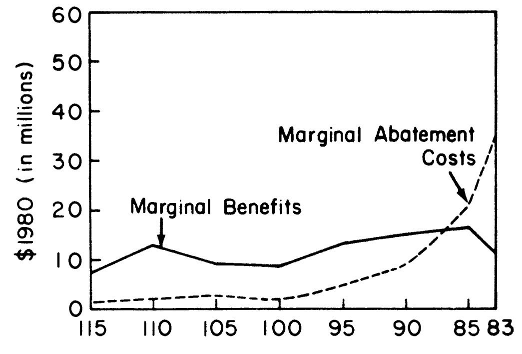

FIGURE 1. LEAST-COST CASE

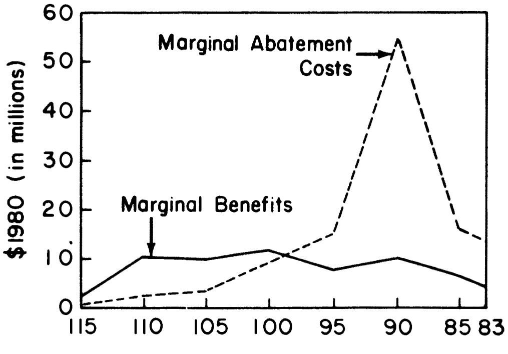

FIGURE 2. COMMAND AND CONTROL CASE

receptors under the IB and CAC regimes. Consider, for example, the TSP levels at receptor 1 under each system. We find that for receptor 1 the TSP level under CAC for a standard of 100 $\mu g/m^3$ is 61.4 $\mu g/m^3$; under the IB "optimum" of 90 $\mu g/m^3$, the TSP level at receptor 1 is 61.6 $\mu g/m^3$. For this particular receptor, then, the less stringent standard under CAC actually results in a higher level of air quality than does the more stringent standard under the least-cost outcome. This is not the case for all the receptors. For example, the binding receptors will obviously have higher TSP concentrations where the standard is less stringent (compare, for example, the TSP levels at receptor 5). Table 2 also makes clear the wide variation in air quality among the various recep-

TABLE 2—TSP CONCENTRATION BY RECEPTOR

Receptor	120	115	110	105	100	95	90	85	83
	Incentive-Based Case								
1.	67.8	67.4	66.2	66.0	65.3	63.7	61.6	59.3	58.6
2.	64.6	63.7	62.2	61.8	60.9	58.7	55.5	51.7	50.9
3.	56.2	56.0	55.5	55.5	55.3	54.6	53.7	52.5	52.2
4.	116.3	113.8	107.8	104.3	100.0	95.5	90.0	85.0	84.0[a]
5.	119.7	115.3	110.4	105.5	100.0	95.2	89.5	84.7	83.5
6.	52.4	51.6	49.1	47.5	46.0	43.4	40.9	38.2	37.6
7.	120.0	114.9	110.4	101.0	99.6	93.0	79.5	53.3	45.4
8.	105.3	102.8	98.9	97.7	95.1	90.4	83.8	74.1	70.1
	Command & Control Case								
1.	65.1	65.0	64.0	62.9	61.4	60.6	59.3	58.4	58.3
2.	60.7	60.4	58.9	57.2	54.9	53.6	52.0	50.7	50.5
3.	54.5	54.4	54.1	53.8	53.2	52.9	52.5	52.1	52.1
4.	109.9	108.7	103.1	99.5	95.2	92.0	87.8	85.0	84.0[a]
5.	120.8	115.5	109.8	104.7	99.6	95.0	89.3	84.2	83.4
6.	45.8	45.5	44.0	42.7	41.0	39.9	38.5	37.6	37.4
7.	106.0	105.8	102.9	94.7	71.9	64.9	58.1	43.9	42.7
8.	97.0	96.5	92.8	88.8	82.5	78.1	73.9	69.8	69.2
	Population-Weighted Averages of Receptor TSP Levels								
IB	77.4	75.7	72.9	70.9	69.0	66.2	62.9	59.3	58.5
CAC	71.1	60.6	68.3	66.2	63.7	62.0	59.9	58.5	58.2

[a] Although the standard is 83 $\mu g/m^3$, there are no controls in the model capable of reducing air pollution at this receptor.

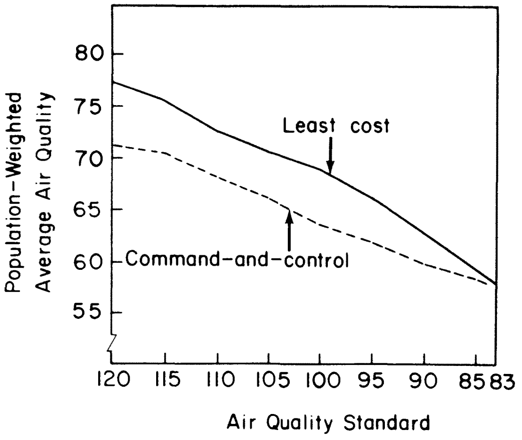

FIGURE 3. POPULATION-WEIGHTED AVERAGE AIR QUALITY UNDER THE LEAST COST AND COMMAND AND CONTROL SYSTEMS

tors; the TSP concentrations at receptors 1, 2, 3, and 6, for example, are far below the standard—in some instances the concentrations are less than one-half of the standard.

In the bottom rows of the table and in Figure 3, we present a summary measure of air quality: a population-weighted average of TSP levels at all 23 receptor points. A comparison of these weighted averages for the "optima" under the two systems reveals that the IB outcome yields a weighted average TSP level of 62.9 $\mu g/m^3$ as compared to the weighted average of 63.7 $\mu g/m^3$ under CAC. Thus, average air quality is only very slightly (probably negligibly) higher under the IB "optimum" than under the CAC "optimum." This is in sharp contrast to the large difference under the two systems in the "optimal" *standard*.

Our first result then is that although the IB regime results in a more stringent "optimal" standard, there is really little difference in overall air quality under the "optima" of our two systems.

The second issue concerns the *total net benefits* of pollution control under the two systems. This calculation is more problematic. The data in Table 1 only allow us to compute the *marginal* net benefits for successively tighter air quality standards beginning with a standard of 120 $\mu g/m^3$. Ideally, we should compare the net benefits of going

TABLE 3—A COMPARISON OF THE CUMULATIVE NET BENEFITS UNDER THE TWO SYSTEMS (MILLIONS OF 1980 DOLLARS)

1. *Incentive-Based Case: Net Benefits from Moving from a Standard of 120* $\mu g/m^3$ *to the "Optimal" Standard of 90* $\mu g/m^3$		
Cumulative MB	$66.17	
Cumulative MC	20.97	
Cumulative Net Benefits	$45.20	
2. *Command & Control Case: Net Benefits from Moving from a Standard of 120* $\mu g/m^3$ *to the "Optimal" Standard of 100* $\mu g/m^3$		
Cumulative MB	$33.86	
Cumulative MC	15.41	
Cumulative Net Benefits	$18.45	
3. *Adjustment of Net Benefits Under the CAC System*		
Cumulative Net Benefits Under CAC		$18.45
Less: Baseline Control Costs in Excess of IB Case		7.81
Plus: Baseline Benefits in Excess of IB Case		28.67
Adjusted Cumulative Net Benefits		$39.31

from a baseline of the totally uncontrolled level of emissions to the optimal standard under each system. (The uncontrolled outcome involves very high levels of TSP concentrations of around 500 $\mu g/m^3$).

We feel that the benefit functions cannot legitimately be extended to value changes in air quality over such extreme levels of TSP concentrations. Consequently, we chose as a baseline the vector of air quality that results from a standard of 120 $\mu g/m^3$. For the IB system, when we sum the differences between the MB and MC curves from this baseline to the "optimal" level of 90 $\mu g/m^3$, we find that the net benefits (from our arbitrary baseline) are roughly $45 million.

Two adjustments must be made to calculate a comparable net benefit estimate for the CAC regime. Recall that, for any given standard (including our baseline), the resulting vector of air quality under the CAC outcome indicates cleaner air than under the IB result. Therefore, we cannot sum the differences between the MB and MC curves from 120 $\mu g/m^3$ to the "optimal" standard of 100 $\mu g/m^3$ and compare this estimate to the IB net benefit calculation. The two calculations have different starting points.

To make the CAC "starting point" comparable to that under the IB system, we must make both a cost and a benefit adjustment. Turning first to the cost adjustment, we find that to go from the uncontrolled level of about 500 $\mu g/m^3$ to our baseline of 120 $\mu g/m^3$, it costs an estimated $7.81 million more under the CAC approach than under the IB system. So for purposes of comparison, we must add to the cumulative costs of the CAC system this additional sum of $7.81 million.

Second, we must make a benefit adjustment. Although we do not attempt to measure the benefits from moving from the uncontrolled state to the baseline for reasons discussed earlier, we must account for the cleaner air (and correspondingly higher benefits) that the CAC outcome provides at the baseline standard. Our benefit functions yield an estimate of $28.67 million for the value of the differentially higher level of air quality produced by the CAC relative to the IB outcome at our baseline standard of 120 $\mu g/m^3$. After making these two adjustments so that the CAC starting point is equivalent to that under the IB regime, we find that the *net* benefits of the CAC scheme are roughly $39 million.

Table 3 summarizes these net benefit calculations including the adjustments needed to permit comparisons between the IB and

CAC outcomes. It is important to interpret these numbers properly. We emphasize that they do *not* provide estimates of the cumulative net benefits under each system; in fact, they greatly underestimate these net benefits because they omit any valuation of the benefits provided by the improvement in air quality from the uncontrolled state to the baseline. And these benefits are no doubt very large. We omit them because (as mentioned earlier) we are not comfortable using our benefit functions to value changes over such extreme levels of pollution. But these benefit figures have been omitted from the estimates for both systems so that cumulative benefits are understated by the same sum for the IB and CAC cases. The figures can thus be used legitimately to compare the net benefits under the two systems.

When we do this, we find that the difference between the cumulative net benefits under the two systems is quite small. As Table 3 shows, the cumulative net benefits under the IB outcome exceed those under the CAC case by only about \$6 million when evaluated at their respective "optima."

It is interesting to contrast this comparison with one in which no consideration is given to the differentials in benefits under the two systems. Suppose, for example, that we were to choose a standard of 100 $\mu g/m^3$ and were simply to compare the costs under the two systems of achieving that standard (under the implicit and mistaken assumption that air quality is the same in both cases). Our computations indicate that the attainment of this standard would cost \$32.7 million under the IB system as compared to \$48.1 million under the CAC regime. We would thus conclude that the CAC approach costs about half again as much to attain the same outcome. But, as we have seen, the outcomes are far from the same.[4]

Finally, we stress once again that while we believe that our findings provide a legitimate basis for comparison between our two prototypical systems, the absolute levels of benefits and costs associated with the various standards must not be taken very seriously. Some sensitivity analysis using upper and lower bounds for our benefits estimates suggests that the "optimal" standard under both systems is quite sensitive to our choice of benefits measures.

IV. Concluding Remarks

The theme of this paper is that IB policies designed to achieve prescribed regulatory standards at least cost may not be so obviously superior to CAC approaches as has been supposed. This will be the case when CAC policies are designed with at least one eye on cost savings—as they sometimes are—and when reductions below the level of the relevant environmental, workplace, or product standards result in beneficial effects. In these cases, the "overcontrol" that makes CAC policies more expensive also makes them more efficacious.

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[4] Although there are considerable differences in the outcomes under our two systems over most of the range of alternative standards for air quality, the outcomes converge as air quality approaches relatively high levels. When we reach a TSP concentration of 83 $\mu g/m^3$, the highest of the standards indicated in our figures and tables, the outcomes under the IB and CAC systems are virtually the same (as is evident in the population-weighted air quality in Figure 3). This occurs because we have now reached the point at which virtually all sources are controlling their emissions to the maximum degree possible under existing control technologies. This manifests itself in the IB case by very rapidly increasing marginal control costs, which are the result of having to introduce control measures in suburban areas in an attempt to reduce pollutant concentrations at the binding receptors which are located in the center city.

These rapidly increasing marginal control costs under the least-cost system have an interesting implication for the design of a regulatory system for pollution control. Following Martin Weitzman's seminal paper (1974) on the choice between quantity and price instruments, our results suggest a strong preference for an effluent fee system over a system of marketable emission permits. In a setting of uncertainty regarding the true benefit and cost functions, a mistake in setting the environmental standard is likely to result in a more costly error when the marginal cost curve is steep relative to the marginal benefit curve in the relevant region. A look at Figure 1 indicates that this is indeed the case for our pollutant at the least-cost outcome. This suggests that the environmental authority should employ the fee approach where errors are likely to be less costly.

One problem with this conclusion, of course, is that neither approach results in the economically optimal outcome in the full sense. We have been careful to describe the standard for which marginal benefits equal marginal costs under either system as the "optimal" outcome, using quotation marks to emphasize that the standard is optimal only with respect to that system. But it is clear that there is an economically superior outcome, namely the Pareto-efficient solution.

One may legitimately ask why we do not reject both of the suboptimal regimes we examine in favor of the first-best outcome. After all, we would seem to have all the information needed to determine the first-best solution. Our response to this question is twofold. First, while it is admittedly an easy matter, in principle, to characterize the first-best outcome, calculating it is a more complicated matter. The characterization is straightforward: the first-order conditions for the economic optimum would have us determine an emissions vector such that *for each source* the marginal benefits from an additional unit of abatement equal marginal cost. This would involve a very complicated general-equilibrium calculation, one that could easily entail a multiplicity of local optima. Nevertheless, with sufficient ingenuity and patience, one might determine this outcome. This solution, incidentally, would typically involve assigning abatement techniques on a polluter-by-polluter basis. Alternatively, one might design some differentiated set of effluent fees to induce the requisite pattern of abatement behavior.

While this may be conceivable in principle, we find it very difficult to see how an environmental agency could implement such procedures. And this is our second, and more basic, point. As the spirit of this paper suggests, we have sought to consider those alternatives that appear feasible in an actual policy setting. The achievement of some selected standards for environmental quality either through a command-and-control approach or through a general incentive-based approach represent alternatives *with precedent* in the policy arena. While the former is certainly the more common, there are now programs (such as EPA's Controlled Trading Program) that make some use of economic incentives to attain the specified environmental standards.

In the choice between the two approaches, we have argued that the case in the literature has been biased in favor of IB measures. However, it is important to put this contention in the proper perspective. One reason that the CAC outcome fares so well in our analysis is that Baltimore air quality authorities employed a somewhat sophisticated and relatively cost-effective procedure for TSP control. Under a less enlightened regulatory regime, control costs could be much higher for equivalent air quality levels.[5]

This brings us to what we see as the basic implication of our findings. They suggest that a carefully designed and implemented CAC system may stack up reasonably well relative to a feasible IB counterpart. However, where CAC standards and implementation procedures are motivated primarily by political considerations (for example, the avoidance of plant closings or of unpopular increases in the cost of local power), CAC policies will get bad marks in comparison to the IB alternatives. Badly designed CAC measures, in short, will yield bad outcomes.

Where, in contrast, economic analysis plays a larger role in CAC standard setting and program design—as it did in Baltimore and does for certain programs at EPA—one may have to take a harder look at such

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[5] As one referee pointed out, our results are also sensitive to the choice of pollutant. To take the extreme case, if there were "perfect mixing" such that an emission of the pollutant at any place contributed equally to pollutant concentrations at all receptor points, then air quality would everywhere be the same. The standard would be binding at all receptors, and there would be no overcontrol under the CAC system to provide differential benefits relative to the IB counterpart. However, where the effects of the pollutant become more highly localized, overcontrol at some receptors will tend to be more pronounced. Our sense is that the pollutant we have used in this study is somewhere to the middle of the "localization spectrum." While volatile organic compounds, for example, exhibit somewhat greater mixing propensities than TSP, many other pollutants including carbon monoxide, "air toxics" (like lead and various chemicals), and certain workplace agents have far more localized effects than TSP.

approaches. Efforts by economists to make CAC measures more effective may, for particular programs, produce outcomes that compare quite well with IB alternatives. Particularly when we take into account real-world regulatory institutions that require uniformity of fees (or in other ways reduce the flexibility needed to achieve the full advantages of the IB approach), incentive-based programs may not clearly dominate well-designed CAC measures.[6]

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[6] We should also note that the argument in this paper relates solely to the *static* efficiency properties of the alternative approaches. Over the longer haul, it is of great importance that we have a system that embodies the appropriate incentives for research and development of new abatement technologies. IB approaches, as economists have long argued, have compelling advantages over typical CAC regimes on this count. Even here, however, there is some scope for designing CAC programs in a way that encourages, rather than impedes, R&D efforts.

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[Footnotes]

[4] **Prices vs. Quantities**

Martin L. Weitzman

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