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STRATEGIES IN WATER QUALITY CONTROL

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Water quality control programs commonly consist of two parts. The first is to determine as public policy the desired quality of a body of water. The second is to implement the policy.

The following article dwells on the second part, comparing three strategies for achieving a pre-determined water quality. The three strategies considered are (1) a system of waste discharge quotas (often called "standards"),¹ (2) effluent charges,² and (3) a waste discharge permits market (sometimes called a "pollution rights" market).³ In contrast to the stationary setting of many treatments of this problem, this article gives particular attention to how these strategies may handle several sources of change that any control program is likely to confront.

Each of the strategies operates through a waste discharge permit system that possesses many common features. These common features are treated first. Then a standard version for each strategy is considered, allowing differences among the versions *only* when required by the *conceptual* differences in the strategies.

THE WATER QUALITY CONTROL BOARD

Assume a Water Quality Control Board receives a mandate to attain and maintain a target quality for a public body of water.⁴ The Board is to achieve the target quality or better within five years.

The Board is empowered to control all waste discharges from non-dispersed, stationary sources, both public and private. It has no control, however, over dispersed sources of waste such as run-off. Within the Board's jurisdiction, no waste can be discharged legally into the body of water without a permit that specifies the maximum rate of

†I am indebted to Blair T. Bower for many helpful comments.

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1. The Delaware River Basin Commission incorporates many of the features attributed in the present paper to the discharge quota system. See A. Kneese and B. Bower, *Managing Water Quality: Economics, Technology, Institutions* 274-281 (1968).

2. Senator William Proxmire has proposed the introduction of effluent charges as a water quality control strategy. See 115 Cong. Rec. 35724-35729 (1969) (Debates on S. Bill 3181, The Regional Water Quality Act of 1970).

See also in Kneese and Bower, *supra* note 1, at 131-42.

3. A system similar to the permits market strategy considered here is described in J. Dales, *Pollution, Property, and Prices* 93-100 (1968).

The system described by T. Ferrar and A. Whinston, *Taxation and Water Pollution Control*, 12 *Natural Resources J.* 307 (1972), is similar to Dales' system, but has a much larger information requirement.

4. The body of water might be of any type, *i.e.*, a lake or river, so long as the major sources of waste were stationary and non-dispersed.

discharge allowed the holder. The Board controls total discharge by limiting the permits issued.

A. Common tasks

The Board has several tasks it must perform in any strategy it attempts. First, it must construct a set of water quality indicators consistent with the specifications of its mandate, and determine the degrading agents. This assumes that a suitable index of water quality is available and that there is only one degrading agent, "waste."

The body of water is divided into "quality regions" sufficiently small that a given rate of waste discharge has the same impact on water quality, regardless of its location within a region. The waste discharge permits are region-specific, *i.e.*, a permit applicable to one region cannot be used for discharges in another. The subsequent discussion deals with the Board's control of pollution of a single quality region.

The Board must establish a monitoring system, either periodic or continuous, to assure compliance of discharges with the permit limitations. The Board also needs a system for monitoring water quality.

From an estimated relationship between waste discharges and water quality, the Board obtains a maximum total rate of discharges consistent with the target water quality. By subtracting a projected rate of discharges from uncontrolled sources, the Board establishes a "target discharge rate," *i.e.*, the estimated maximum rate of discharge from *controlled* sources consistent with the target water quality.

B. Sources of change

The Board faces one certainty; it will operate under conditions of constant change. These changes may affect (1) the target discharge rate applicable to any given target water quality, (2) the cost-minimizing allocation of permits among potential waste dischargers, and (3) the target water quality mandate of the Board.

1. *Target discharge rate.* The target discharge rate is subject to revision as the Board becomes aware of changes in three basic determinants. First, the Board may acquire an improved estimate of the waste-discharge-to-water-quality relationship. The continuing controversy over the role of phosphates in the eutrophication of lakes should be a sufficient reminder of the uncertainty on this count. Second, there may be unpredicted changes in uncontrolled sources. This source of change may be particularly important in agricultural

regions. Third, the waste assimilative capacity of the water body may be altered by changes in such factors as the construction of new dams, the policies governing existing water impoundments, and the amount of dredging or silting. Changes in any of these factors, and others, will alter the basic relationship between the rate of waste discharge and water quality.

2. *Cost-minimizing allocation of permits.* One of the primary criteria for evaluating control strategies is the cost of attaining any given water quality. All else being equal, the cost-minimizing strategy is preferred. Any change in conditions that might change the cost-minimizing allocation of permits therefore constitutes a change to be reckoned with. Such changes may come from a variety of sources, e.g., increased industrialization or urbanization of the neighboring land, changes in product mix and production technologies, or changes in waste treatment technologies. These matters are discussed in more detail in a later section.

3. *The mandate.* Although we may hope that changes in the Board's mandate (i.e., the target water quality) are infrequent, this is a contingency the Board may confront. The demand for water resources, both for waste disposal and other uses. Recreation, for instance, is in constant flux. The target water quality of today may seem inappropriate tomorrow.

Our attitude toward the strategies should depend in large measure on how they are able to cope with changing conditions.

EVALUATION CRITERIA

Criteria for evaluating the strategies include (1) cost, (2) equity, (3) ease of enforcement, and (4) generation of revenue. An important fifth consideration that cannot be properly treated with the present general framework is the impact of the strategies on the distribution of welfare, i.e., the incidence of the costs and benefits of the strategies.

A. Cost

Other things being equal, the preferred strategy is that which minimizes the cost of achieving the target water quality. The total cost consists of two parts; the "abatement costs" incurred by potential waste dischargers and the "administrative costs" incurred by the Board. Consider first the abatement costs.

1. *Abatement costs.* A necessary condition for the minimization of abatement costs is that all polluters have the same *marginal* cost of abatement, i.e., that the cost of reducing the rate of discharge by one unit be the same for all polluters. Otherwise, the cost of obtaining a

given water quality can be reduced by the low marginal abatement cost polluter reducing his discharges by some amount and the high marginal abatement cost polluter increasing his discharges by the same amount. The total rate of discharges remains unchanged, but the resource cost of abatement is lower.⁵

In considering the cost of abatement, it is important to differentiate between waste "abatement" and waste "treatment." Treatment is but one form of abatement. Other important, though less visible, forms of abatement reduce the total amount of waste generated.

For example, a firm may change its product-mix, shifting output from high waste-generating goods to low waste-generating goods. Or it may reduce the waste generated by changing the production processes by the use of higher quality inputs, the introduction of re-cycling processes, or the use of techniques that do the same job but either generate less waste or make the waste generated easier to treat or re-cycle.

Each of these forms of abatement generally increase the cost of production. Often, they also complicate the task of determining net abatement costs by changing the nature of the good produced. For example, higher quality inputs may improve product quality. The net increase in abatement cost is then something less than the increased input cost.

2. *Administrative costs.* Three aspects of administrative costs are important—the costs of (1) collecting and processing the information required for the Board's operations, (2) enforcing the Board's decisions, and (3) making non-routine decisions.

B. Other criteria

1. *Equity.* Questions of equity are easier raised than resolved. What a person considers "fair" often depends on where he is standing. The less ambiguous the criteria for allocating the permits, however, the less frequent should be the claims of unfair and arbitrary treatment. There is also a probable consensus that the Board should be isolated from political pressures and economic threats.

2. *Ease of enforcement.* In addition to the role of enforcement in determining administrative costs, ease of enforcement may affect the success of the Board in achieving the target water quality on schedule. Enforcement is also related to the question of equity, since

5. We ignore here complications that may arise if important economies of scale are present in the abatement efforts of potentially large dischargers. The presence of this situation in a quality region may require its treatment as a special case. See Kneese and Bower, *supra* note 1, at 137-38.

a strategy that produces few claims of "unfair treatment" (justified or not) will generally be easier to enforce.

3. *Revenues.* The effluent charge and permits market strategies generate revenue for the Board from polluters proportional to the rates of waste discharge. The discharge quota strategy would probably be financed by some combination of licensing fees (not proportional to discharges) and general tax revenues.

The charge and market systems might therefore be favored on the ground that the Board is an acting trustee of a common property resource and should receive revenues from the parties responsible for the degradation of the resource in proportion to the amount of degradation.

This position might be contested by those who feel that polluters have established "prior rights" to pollution by their past practices. Ferrar and Whinston appear to hold this position.⁶ It is difficult to see the basis for the position, however, since there are few, if any cases in which the courts have recognized a "right-to-pollute" strictly on the basis of prior behavior. Free use of a public resource that results in degradation of that resource may be a privilege; it is certainly not a right.

No more will be said of the revenue question.

THREE STRATEGIES

A. *Discharge quotas—mechanics*

With the discharge quota strategy, the Board allocates the target rate of waste discharge among applicant polluters on the basis of such factors as the cost of abatement, "technological feasibilities," and (probably) political pressures. Each applicant receives a permit to discharge waste up to some maximum rate for each of the next five years, with the total maximum rates of all applicants consistent with the target rate of discharge in the fifth year.

It is likely that a portion of the target rate of discharge (*i.e.*, 10 percent) would initially be held in reserve as a contingency against increased urbanization and industrialization (with the associated applications for waste discharge permits), and as a hedge against revisions in the target rate of discharge.

Once the contingency reserve has been exhausted, the Board must either (1) place a moratorium on further discharge increases, (2) allow "over-runs" (*i.e.*, violate its mandate), or (3) modify previously allocated quotas. In any event, the Board must repeat the entire

6. Ferrar and Whinston, *supra* note 3, at 5-6.

allocation process periodically, simply to maintain the target water quality beyond the first five years.

B. Discharge quotas—evaluation

How does the discharge quota strategy fare by our four criteria? In general, it fares poorly. The cost of achieving any target water quality will probably be high, relative to either of the alternative strategies. It is also likely to have more questions about its equity and more enforcement difficulties.

1. *Cost.* It is not clear that minimization of the resource cost of obtaining the target water quality would be the primary criterion for allocation of the permits. If it is, however, the Board confronts a two-edged sword. Any increase in its effort to minimize abatement costs requires an increase in the information collection and processing component of administrative costs. Thus, as abatement costs fall, administrative costs rise.

The search for the necessary abatement cost data is likely to become very costly as the Board proceeds from treatment to other abatement data. Although the applicant polluters may have ready access to the data, they may consider much of it confidential and be resistant to its release. The Board can, within limits, generate much of the data independent of applicant sources, but only at a substantial cost.

We must also remember that the Board is attempting to minimize these costs over a five year period during which substantial technological change will occur. The Board faces a formidable task as it attempts to lower abatement costs.

Administrative costs are also likely to be high. As noted above, efforts to reduce abatement costs increase the information costs of the Board's operations. Additional administrative costs are also incurred each time the Board determines quotas for future years (beyond the initial five years) and each time it must modify past quota allocations. In a sense, every allocation decision made by the Board is non-routine.

Finally, enforcement costs may be high for reasons given below.

2. *Other criteria.* Beyond attempting to minimize costs, the basis for allocating quotas is unclear. In the absence of unambiguous criteria, the allocations have an air of arbitrariness that may beg for charges of unfair treatment. It places a premium on the ability of interested parties to articulate their positions and makes the Board more vulnerable to political pressures.

Also, efforts to reduce total abatement costs may cause the Board

to reward inefficient polluters with high discharge quotas at the expense of those who have managed to attain low treatment costs.

The Board thus faces the possibility of a firm or municipality fighting the quota given it on the grounds that it has received "unfair treatment," can meet the quota only at a "prohibitive cost" (possibly forcing a firm to shut-down or relocate), or that the quota is "technologically impossible" to meet. If the Board modifies the quota, other polluters are encouraged to contest their quotas. If the Board takes legal action to obtain compliance, a prolonged court fight may result. Regardless of the outcome, whether settled in court or out, the contested quota absorbs costly resources of both parties.

C. Effluent charges—mechanics

The basic concept of effluent charges is simple. The Board establishes a price, or "effluent charge," for the waste discharge permits proportional to the maximum permitted rate of discharge, say, ten cents per pound per day. Once the Board has established a price, the individual applicant determines his permitted rate of discharge.

The individual dischargers are then paying for the use of a common property resource, the public body of water, and may be expected to respond to its price the same as they respond to the prices of other resources such as labor. The higher the price, the less of the resource used. Confronted with a higher price for the use of the waste assimilative capacity of the water, many polluters will find it less costly to reduce the rate of waste discharge by using some combination of the forms of abatement described earlier such as changes in product mix, production processes, and waste treatment.

The Board might base the initial charge on estimates of abatement cost functions of the major polluters, estimated waste treatment cost functions (recognizing that abatement costs never exceed waste treatment costs and are normally less), or (moving to smaller information requirements) cost estimates of "typical" operations. The Board may use a questionnaire survey of the potential applicants as supplementary data, asking how much they would discharge at various effluent charges.

The effluent charge is then adjusted, perhaps annually, in the direction required to move water quality toward the target level. These adjustments take into account changes in any factors affecting water quality, changes in the mandated target water quality, and changes in factors (such as the level of industrial activity) that might influence the demand for the permits. Note that the Board can respond directly to movements in water quality. Errors in the estimation of the target discharge rate raise fewer problems for this strategy

than for strategies that must respond more directly toward the target waste discharge rate.

D. Effluent charges—evaluation

How does the effluent charge strategy fare by our four criteria? In general, it fares well. The costs of achieving the target water quality should be relatively low, the strategy raises few questions of equity, and there should be relatively few enforcement problems.

1. *Cost.* Abatement costs are minimized. Each firm faces the alternatives of abating waste discharges or purchasing permits for discharge at a price common to all polluters. Choosing the less costly alternative, each polluter should increase abatement until the marginal cost of abatement equals the effluent charge. In this manner, the marginal costs of abatement of all polluters are equated and total abatement costs minimized. As conditions change, polluters continue to adjust abatement in such a manner that the cost of achieving any given water quality is minimized.

The same cost-saving incentive will produce decreasing rates of discharge (even with a constant effluent charge), as polluters search for new production and waste treatment technologies that lower their total waste handling costs.

The administrative costs of the strategy should also be relatively small. The major information costs are incurred to establish the initial effluent charge. These costs need not be large (relative to other strategies) so long as the initial effluent charge is considered truly *initial*, subject to change as information increases and basic conditions change. No thought should be entertained (silently or aloud) that the Board is able or needs to fine tune a "right price," with its connotations of permanence.⁷

If it is recognized by all that periodic adjustments in the charge will be made as needed to achieve the desired improvement in water quality (regardless of whether they are precipitated by improvements in our knowledge of basic determinants or by changes in those basic

7. Ferrar and Whinston seem overly concerned about the possible effects of economic growth on the operation of the effluent charge strategy. Ferrar and Whinston, *supra* note 3. They apparently see the Board continually one year late in its efforts to maintain the target quality, as its failure to anticipate economic growth causes the rate of discharge always to be excessive by 5 percent or so.

In addition to attributing virtually no anticipatory capacity to the Board, this concern attaches an exaggerated precision to estimates of the target rate of discharge. Our knowledge does not allow specification of water quality characteristics and their effects so precisely that fluctuations of 5 percent or so in the waste discharge rate are normally of measurable consequence.

See Fed. Water Pollution Control Ad., Dep't of the Interior, Report of the Committee on Water Quality Criteria (1968) (Washington, D.C., G.P.O.).

determinants), these adjustments should be relatively routine. In contrast to the discharge quota strategy, virtually all decisions in the effluent charge strategy are routine. As we shall see, enforcement costs should also be lower.

2. *Other criteria.* With effluent charges, the efficient abater is rewarded by lower payments to the Board for discharge permits. The inefficient abater pays a price for his inefficiency. Also, since the effluent charge is the same for all polluters, it is difficult for one of the polluters to cry "unfair treatment." The same feature decreases the vulnerability of the Board to public relations and political pressures.

Finally, under the discharge quota strategy, there was the potential problem of a firm fighting its quota on the grounds of "technological impossibility" or "prohibitive cost." With the effluent charge strategy, there can be no appeal to technological impossibility. The decision of an individual firm to abate or discharge belongs to the firm. Likewise, the appeal to prohibitive costs would seldom sound authentic, since effluent charges paid should represent a relatively small addition to total costs. Enforcement problems will not disappear with effluent charges, but they should be substantially less than those associated with the discharge quota strategy.

E. Waste discharge permits market—mechanics

With our final strategy, the Board establishes a schedule of maximum discharge rates for each of the next five years, with the rate in the fifth year being the target rate of discharges (the maximum rate estimated to be consistent with the target water quality). This schedule of *total* discharge rates is identical to the one used in the discharge quota strategy.

Instead of allocating total permitted discharges among the polluters as free quotas, however, the Board establishes a market in transferable discharge permits. One way to establish the market is for the Board to hold an initial auction for the permits applicable to the first five years, followed by annual auctions to add to the market the supply of permits for the twelve-month period five years distant. Since the permits are transferable, a market in the permits also operates outside of the Board's auctions.

With a market in discharge permits, a firm chooses the least-cost method of handling its waste problem; either abating or buying permits with terms of one to five years for discharge into public waters.

In some discussions, it would seem that little more need be said about the mechanics of the permits market. J. H. Dales summarizes:

Such markets would automatically set the correct level of pollution charge . . . and would also automatically, and continuously, adjust the level of the charge to take account of economic growth.

He sees "a simple market that can be operated by three or four people and a small staff of stenographers to register purchases and sales."⁸

Such might be the case, provided two conditions are satisfied: (1) the permits market approximates a perfectly competitive market (in particular, that all participants are small, relative to the market), and (2) the target rate of waste discharges for any year remains constant once it has been established.

It is unlikely, however, that the target rate of discharges can be set with certainty several years (three to five) in advance. Changes are likely from the many sources previously cited, and the Board needs some provision for handling them. One provision might be a contingency reserve of permits, say, 10 percent of the total, held off the market by the Board to meet unexpected developments. But a contingency reserve is no more the whole answer here than with the discharge quota strategy. Another provision might be for the Board to enter the market as a buyer. Entry by the Board, however, may force significant increases in the price of permits, raising questions of "excess profits" for the sellers and issues of equity for new market entrants during periods of a contracting supply of permits.

Nor can we assume, *a priori*, that the market will approximate perfect competition. Two forces will work toward creating imperfect conditions. First, the permits are region-specific. This feature may significantly narrow the scope of the market. (Permits applicable to Lake Superior will be of little use to a firm wanting to build a new plant on Lake Michigan). Second, once purchased, many of the permits will be associated with long-term investment decisions in basic patterns of production and waste treatment. In the short-term the holders of these permits will be relatively price insensitive.

Thus, at any given time only a small portion of the total supply of permits will be sensitive to changes in their price. The direct result is a strong possibility of monopolistic elements in the market. These features may be especially troublesome to a potential new firm in a region that must acquire permits for some minimum rate of waste discharge. When the new firm tells the Board that it cannot acquire the needed permits or can acquire them only at "exorbitant" prices, how should the Board respond?

At least some of the proponents of a permits market strategy

8. Dales, *supra* note 3, at 100.

evidence concern over the operation of an unattended market. Dales sees the Board acting "like a 'specialist' on organized stock exchanges" to guard against sudden changes in the price of permits.⁹ Although Dales does not describe the source of this potential problem, the most plausible reason for unstable permit prices is a narrow market. Given his comment about the market being operated by "three or four people and a small staff of stenographers," however, the problem does not really trouble him.

Ferrar and Whinston show concern for the speed of adjustment of a free market. They feel that "the complexity of the information involved . . . would tend to inhibit effective communication among participants." To remedy this flaw, Ferrar and Whinston would give the Board the task of "centralized coordination." The information requirements of their proposed mechanism, however, appear quite similar to those of the discharge quota strategy, since they have the Board estimating the waste *treatment* cost functions of all major polluters. In their discussion, they fail to distinguish between waste *treatment* and waste *abatement* costs, thereby seriously underestimating the information requirements of their system.¹⁰

Both discussions dismiss quite lightly these market difficulties, with virtually no justification, and they fail to even address several problems the Board might expect to confront. How serious would these problems be, and how might the Board deal with them? We don't know. More research, both conceptual and empirical, is needed before the permits market can be fairly evaluated as a control strategy.

F. Waste discharge permits market—evaluation

How does the permits market fare by our four criteria? Its performance depends critically upon the nature of the market.

1. *Cost.* Under *perfectly competitive* market conditions, the abatement cost of attaining any given water quality is minimized. To the extent that monopolistic elements exist in the market, however, the marginal cost of obtaining permits is likely to be greater than the price of the permits, and the marginal gain from selling a permit less than its price. With this divergence, it is unlikely that the marginal abatement costs of all polluters will be equal. Thus, under *imperfect* market conditions, abatement costs are *not* minimized.

Likewise, if the permits market operates smoothly and changes in the target discharge rate are minor, administrative costs should be close to those of the effluent charge strategy. Lacking these ideal conditions, administrative costs of the permits market strategy are

9. Dales, *supra* note 3, at 93-95.

10. Ferrar and Whinston, *supra* note 3, at 12-14.

likely to be greater. The Board needs additional mechanisms for decreasing the total supply of permits, and for evaluating the performance of the market and interfering if it decides the market is not behaving "properly." These are new enterprises for the Board, involving non-routine decisions, and could result in substantial additions to administrative costs.

Given conditions of change and market imperfections, the cost of achieving the target water quality with a permits market strategy could be significantly higher than needed with the effluent charge strategy.

2. *Other criteria.* If the market operates smoothly, its equity and enforcement characteristics should be similar to those of the effluent charge strategy. Each occasion of market intervention by the Board, however, is accompanied by potential problems of both equity and enforcement. It is even conceivable that these problems could be as serious as those encountered with the discharge quota strategy.¹¹

CONCLUSIONS

The differences among the strategies are almost non-existent in a stationary world with perfect competition and costless information. This is hardly an accurate description of the world in which we operate, however. The problems associated with the discharge quota strategy are very evident in a setting of changing conditions with imperfect and costly information. The discharge quota strategy is inferior by each of the criteria considered.

The permits market strategy does better, especially if one is selective in the complications allowed to enter the picture. Thus, if it is assumed that no revisions of the target rate of discharge will be necessary and that permits market will sufficiently approximate perfect competition, the market strategy does well on nearly every count. But revisions in the target rate of discharge probably will be necessary, and we have reasons to expect problems to arise in the operation of the market. Although the seriousness of these difficulties is not known, they cast significant doubt on the merits of a permits market as a general control strategy.

In a changing and imperfect world, there can be no ideal strategy for all situations. The low information requirements of the effluent charges system and its ability to react to a broad class of changing conditions appear to rank effluent charges as the superior control strategy in a wide range of situations.

11. There is a strong similarity between the case cited earlier of a firm protesting its discharge quota on the grounds that it involves prohibitive costs or is technologically infeasible, and the case of a firm that cannot acquire in the market permits for some minimum rate of discharge, or can do so only at an exorbitant cost.