Comment on 'An Effluent Charge Schedule: Cost, Financial Burden, and Punitive Effects' by E. Downey Brill, Jr., Charles S. ReVelle, and Jon C. Liebman

RICHARD L. REVESZ

Ralph M. Parsons Laboratory for Water Resources, Department of Civil Engineering, Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

In their paper, Brill et al. [1979] propose an effluent fee schedule in which the unit charges are a function of the level of pollution abatement. The purpose of this discussion is to offer some comments on the theoretical basis and relative merits of their approach.

THEORETICAL CONSIDERATIONS

In the Pigouvian tradition the proper level of a tax upon the generation of an externality is equal to the marginal net damage produced by that activity, where net damage is defined as the difference between marginal social and private damage [Baumol and Oates, 1971]. In this way, whenever the benefits to society of a reduction in an emission exceed the costs of this reduction, the polluting firm will realize a net saving by cutting back on its effluents rather than paying a charge on them. In contrast, when a reduction in emissions is not worth its cost to society, it will also be unprofitable for the polluter.

The difficulty of estimating the benefits of pollution abatement and the even greater difficulty of calculating marginal net benefits have led many economists to abandon their quest for 'ideal' fees [Mills, 1975; Baumol and Oates, 1979]. As a substitute, they suggest that environmental authorities formulate a set of quality goals and then determine by empirical analysis and experimentation the taxes necessary to achieve these goals. Baumol and Oates [1979] label these taxes as 'second best' substitutes to ideal fees when they achieve the same effect as the cost minimizing solution obtained by a central planner. In an earlier paper [Baumol and Oates, 1971] they show that constant unit taxes possess second best properties provided that they are equal to the shadow price of the pollution constraint. They do not, however, derive the general second best conditions. These will be presented in the following section and will be compared to the tax schedule proposed by Brill et al. [1979].

SECOND BEST CONDITIONS

Let $x_v$ represent the quantity of input $i$ used by plant $v$ ($i = 1, \ldots, n; v = 1, \ldots, m$), $z_v$ be the quantities of waste it discharges, $y_v$ be its output level, $f(x_{v1}, \ldots, x_{vn}, z_v)$ be its production function ($f$ is concave), $p_i$ be the price of input $i$, and $k$ the desired level of $\sum z_v$, the maximum permitted daily discharge of waste. The cost minimizing problem for a central planner may be stated as

$$\min F = \sum_i \sum_v p(x_{vi})$$  \hspace{1cm} (1)

subject to

$$y_v = f(x_{v1}, \ldots, x_{vn}, z_v), \quad v = 1, \ldots, m$$

$$\sum_v z_v = k$$

By using $\lambda_v (v = 1, \ldots, m)$ and $\lambda$ as the $(m + 1)$ Lagrange multipliers the first-order conditions are given by

$$\lambda_v \frac{\partial f}{\partial z_v} + \lambda = 0, \quad v = 1, \ldots, m$$  \hspace{1cm} (2)

$$p_i + \lambda \frac{\partial f}{\partial x_{iv}} = 0, \quad v = 1, \ldots, m, \quad i = 1, \ldots, n$$

If these $m$ plants are run independently with the objective of minimizing the costs of the outputs the firm produces and each firm faces a unit tax $t(z_v)$, each firm's problem can be stated as follows:

$$\min F = t(z_v)z_v + \sum_i p_i x_{vi}$$  \hspace{1cm} (3)

subject to

$$y_v = f(x_{v1}, \ldots, x_{vn}, z_v)$$

The first-order conditions for this problem are given by

$$\lambda_v \frac{\partial f}{\partial z_v} + t(z_v) + \frac{dt(z_v)}{dz_v} z_v = 0$$  \hspace{1cm} (4)

$$p_i + \lambda \frac{\partial f}{\partial x_{iv}} = 0$$

From (2) and (4) one sees that the decentralized and least cost decisions will lead to the same allocations if and only if

$$t(z_v) + \frac{dt(z_v)}{dz_v} z_v = \lambda$$  \hspace{1cm} (5)

The solution to (5) is given by

$$t(z_v) = \lambda + \frac{c}{z_v}$$  \hspace{1cm} (6)

where $c$ is an arbitrary constant.

Then the charges paid by plant $v$, $T(z_v)$, are

$$T(z_v) = t(z_v)z_v = \lambda z_v + c$$  \hspace{1cm} (7)

Any tax scheme which satisfies (7) is a second best alternative to an ideal fiscal method.

THEORETICAL CLASSIFICATION OF BRILL ET AL.

Brill et al.'s [1979, p. 994] tax scheme is given by

$$t(i) = g - h_i$$  \hspace{1cm} (8)
where \( g \) is the maximum unit charge, \( h \) is the decrease in unit charge per unit of waste removal efficiency, and \( I \) is the waste removal efficiency. The expression may be written as

\[
T(z) = g - h\left[1 - \frac{z}{z_0}\right] = (g - h) + h\frac{z}{z_0} \tag{9}
\]

where \( z_0 \) is total waste production. Since the authors do not arrive at this tax by equating marginal net benefits and marginal costs, their solution is not ideal; from (6) and (9) it follows that, in general, it does not meet second best conditions. However, if

\[
g - h = \lambda
\]

and if

\[
z < z_0 \left(\frac{g - h}{h}\right) \quad z \leq z_a \tag{10}
\]

the scheme will approximate the second best solution in the range \( 0 \leq z \leq z_a \) and will only differ substantially from constant charges for relatively low pollution abatement efficiency.

This discussion places the study in the context of recent theoretical developments and shows that, in general, the approach used is not optimal and that when it is optimal, it is merely a constant unit charge scheme. The following sections will address the issues of practicality, punitive charges, and optimality conditions.

**PRACTICALITY**

*Brill et al.* [1979, p. 994] state that the large financial burden that constant unit charge programs place on polluters 'would account for significant opposition to the implementation of such charge programs' and that this 'may affect the degree of cooperation from industrial and municipal discharges during the planning and implementation processes' [*Brill et al.*, 1979, p. 993].

While high taxes are undoubtedly unpopular and may indeed force plant closings or cutbacks and while cooperation between the dischargers and the pollution control authority is highly desirable, it is not clear that the approach suggested by the authors provides a solution to these problems. Indeed, since the tax scheme suggested by *Brill et al.* [1979] is dependent on the total discharge level \( z_0 \), the polluters have an incentive to overstate this level. When the polluters consider \( z_0 \) to be a decision variable, their optimizing problem becomes

\[
\min T(z, z_0) + \sum_{i} p_i x_i \tag{11}
\]

subject to

\[
y_i = f(x_i, \ldots, x_m, z) \quad z_0 \leq z^* \tag{12}
\]

where \( z_0^* \) is the highest initial amount an individual polluter feels that he can reasonably defend before the regulatory authority. In general, this minimization problem has a corner solution at \( z_0 = z_0^* \). This behavior would leave the regulatory authority with little choice but to determine a 'normal' level of total emissions to serve as a point of reference, a procedure which would lead to disputes with polluters who felt that their assigned benchmark was unfair.

Thus the implementation of *Brill et al.*'s [1979] plan presents serious problems, as it could produce protracted court fights centering on the definition of normal total emission levels. An important side effect of this result is that if the initial pollution level were misrepresented, the tax scheme would depart significantly from the least costly program (since the parameters \( g \) and \( h \) are calibrated for a given \( z_0 \)).

Finally, by not considering the possibility of a redistribution of the income generated through taxation the authors overlook what probably constitutes the major source of financial relief for the polluters. While all redistribution schemes present important equity problems, these problems should be considered an integral part of the taxing scheme.

**PUNITIVE CHARGES**

*Brill et al.* [1979, p. 997] label taxes which produce no significant waste removal as punitive charges. This definition is dependent on the assumption of strictly convex marginal costs that rise very steeply for a limiting degree of waste removal. However, extensive evidence [Graves, 1972; Thomann, 1974; *Baumol and Oates*, 1979] suggests that marginal cost curves do not exhibit the shape suggested by the authors. In municipal plants, nonconvexities arise from the transition from primary to secondary treatment and, in industrial waste treatment plants, from possible changes in the production processes. Thus it is only correct to talk about punitive charges in the context of very high water quality, since cost curves are locally convex in this region.

Furthermore, to reduce the unit charge to zero once the specified limiting level of waste removal had been provided [*Brill et al.*, 1979, p. 997], the regulatory authority would need a detailed knowledge of the production technologies of the polluter. As in the case of the initial emissions level discussed in the previous sections, the process of eliciting this information would seriously hamper cooperation between the authority and the polluters and negate the major benefit of the scheme suggested by the authors.

**OPTIMALITY CONDITIONS**

The authors state that each discharge is expected to reduce wastes to the point where marginal savings equal marginal costs, given that total savings exceed total costs [*Brill et al.*, 1979, p. 993]. This statement provides neither the necessary nor the sufficient conditions for optimality. Consider the objective function of the polluters

\[
\min T(z) + C(z) \tag{12}
\]

subject to

\[
z \leq z_0 \tag{13}
\]

where \( z_0 \) is the initial level of emissions and \( C(z) \) is the cost of pollution abatement (by definition \( C(z_0) = 0 \)). Let

\[
S(z) = T(z_0) - T(z) \tag{14}
\]

where \( S(z) \) is the tax savings obtained by pollution abatement.

The first-order conditions are given by

\[
C(z) - S'(z) \geq 0 \quad z < z_0 \tag{15}
\]

\[
C(z) - S'(z) = 0 \quad z = z_0 \tag{16}
\]

\[
C(z) - S'(z) > 0 \quad z = z_0 \tag{17}
\]

The requirement that total savings be greater than total costs is unnecessary, since the introduction of the constraint \( z \leq z_0 \) allows for the corner solution \( z = z_0 \). On the other hand, the
following second-order condition is needed to assure optimality:

\[ C''(z) - S''(z) \geq 0 \quad (15) \]

The latter requirement becomes particularly important when nonconvex cost functions are present.

**Summary**

*Brill et al. [1979]* present an alternative to both ideal and second best fees. However, the novelty of their approach is clouded by its similarity to constant unit charge methods when high removal efficiencies are required and because its disadvantages in terms of reduced efficiency do not seem compensated by increased practicality. Furthermore, the use of the optimality conditions provided by the authors could lead to important errors when realistic cost functions are used.