**Water Pollution Taxes:
A Good Idea Doomed to Failure?**

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Abstract

Water pollution taxes, or effluent fees, have long been advocated by environmental economists as a regulatory approach to cost effectively achieve water quality improvements. The article reviews the arguments in favor of taxes and traces the history of the idea in U.S. policy debates. Particular attention is given to the institutional challenges presented by a tax system and its application in watershed contexts where transport phenomena are important. The article also addresses the question of why effluent taxes are so rarely seen in practice.

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Introduction

Economists have long advocated pollution taxes as a policy to improve water quality. One of the reasons water effluent taxes are embraced by economists interested in market-based policies is that sources of water pollution are varied and difficult to assess individually in terms of control costs. In principle, taxes overcome this problem. With a price—the tax—applied to pollution emissions, firms compare the price to their costs of emissions control. If the price is higher than control costs, they reduce emissions rather than pay the tax. Accordingly, with a price mechanism, high-control-cost firms abate less and low-control-cost firms abate more. When high-control-cost firms abate less than low-control-cost firms, a given level of pollution reductions is achieved at the least cost. Also contributing to the motivations for a tax approach are the way in which taxes promote innovation (relative to static quantity-based regulations) and the fact that taxes generate revenue.[1] This last characteristic is particularly pertinent since many water quality projects involve large investments in infrastructure. Treatment plants, sewer systems, and flow control devices like dams require large chunks of public financing. Taxes promise a ready source of funds.

Given these advantages, it is noteworthy that effluent taxes have not been widely adopted. One of the questions addressed by this article is why effluent taxes are so rarely seen in practice. The reasons lie both in politics and in economics. Relative to "command-and-control" regulations—such as numerical, permit-based effluent limits—taxes are particularly desirable when pollution control costs vary across sources and are difficult for regulators to measure. However, taxes have distributional characteristics that are far different from command-and-control regulations. In particular, taxes require polluters to pay control costs as well as taxes on emissions that are not controlled. Command-and-control policies only require polluters to pay

control costs. This is a significant distributional difference that may explain the political demise of effluent tax policies.

A greater focus of this article, however, is on the institutional challenges presented by, and the efficiency of, effluent taxes. Depending on the type of system imposed, taxes do not guarantee more efficient outcomes than more standard forms of regulation. And, leaving politics aside, it can be institutionally demanding to put in place a system of effluent fees guaranteed to produce markedly better outcomes than more conventional systems of regulation. But, despite these difficulties, there remains a strong set of arguments for the use of taxes to control water pollution. The article will explore both the challenges and opportunities of a tax system. In particular, we will characterize the informational and institutional barriers to successful implementation of water quality taxes.

A distinguishing feature of the water quality problem is that environmental damages—that is, the costs to society of pollution—are highly dependent on the location of pollution sources in the hydrological, social, and economic landscape. First, the demand for water quality varies from location to location. Some waterbodies are envisioned as pristine, where recreation and species support is the overriding concern. Other waterbodies, such as those in urban areas where industrial effluent and development-related runoff are practical facts of life, serve a more complex set of objectives. Second, a source's location determines the way in which pollution ultimately affects surface waters. The transport, diffusion, and cross-pollutant interactions of releases are highly idiosyncratic to location. Upstream releases may be worse than downstream releases, because upstream pollution affects a longer stretch of the river course. Riparian releases will tend to be worse than inland releases since there is a more direct hydrological connection between the pollution and surface waters. Natural degradation and chemical interactions are also highly landscape-dependent. For these reasons, uniform taxes may not satisfy water quality objectives or—putting it the other way around—if used to satisfy quality objectives, may not yield minimum aggregate control costs. Spatial issues arise in most environmental tax contexts. They are particularly important in the case of water quality, however, because the transport and deposition of water pollutants are dependent upon a particularly complex set of forces that are difficult to measure and model.

We will explore these political, institutional, and economic issues in more detail by reviewing the literature on effluent taxes, the limited international experience with imposing such taxes, and the current state of water quality regulation in the United States.

1. The Existing Approach to Water Quality Regulation

Before turning to a description of effluent taxes, it is useful to briefly describe the status quo approach to regulation: command-and-control effluent reduction requirements.[2] The centerpiece of U.S. water quality regulation is the National Pollutant Discharge Elimination System (NPDES) permit program. The NPDES program requires polluters to obtain permits, or licenses, to discharge. These permits specify pollution amounts that can be legally discharged. The limits are determined by reference to the "best conventional" control technology or "best economically achievable" control technology, depending on the type of pollutant. The control technology standard in turn typically generates numerical concentration and aggregate volume limits. Limits may also take the form of "allowable discharges per unit" of a facility's production. It is these numerical limits that are binding. The actual technology used to achieve these numerical standards is up to the polluter. For our purposes, the essential characteristic of this system is that it sets numerical, quantity-based limits on pollution. We refer to this system as the "effluent standards approach."

It is important to note that NPDES permits are only required of so-called "point sources." Point sources tend to be larger industrial and commercial facilities and public treatment facilities. Some large agricultural operations are considered point sources, but, by and large, runoff from farms, roads, lawns, and most small pollution sources are not directly regulated. These "nonpoint sources" are the subject of increased scrutiny, since most of the nation's remaining water quality problems are due to nonpoint pollution.[3]

In addition to the technology-based standards described above, regulation can impose additional controls on point sources if the waterbody to which discharges occur is in violation of state water quality standards. Accordingly, these ambient water quality standards are a second line of defense if baseline standards fail to achieve water quality goals. This tightening of permit conditions only works, however, if point sources are the source of the water quality violation. If nonpoint sources are to blame, some other mechanism must be called into play. This is one rationale for the so-called Total Maximum Daily Load (TMDL) program. A long-neglected aspect of the Clean Water Act (CWA), TMDL provisions require states to identify waters that are not in compliance with water quality standards, establish priorities, and implement improvements—including improvements that rely on nonpoint source reductions.[4]

In the future, the TMDL approach and the need to control nonpoint sources are likely to expand the nature of regulation. The nature of the nation's water quality problems make this almost inevitable, though many legal, technical, and political hurdles remain to be cleared.

Starting from the *in situ* quality of waterbodies themselves and working backwards to address threats to quality sounds like simple common sense. It is, but it is not how one would describe the current regulatory system. The focus of the current system is on specific numeric discharge limits applied to a precisely defined universe of pollution sources. The quality of surface waters themselves is a binding regulatory issue only if quality is adequately monitored and if point sources are found to be the source of the problem.

Effluent taxes could play an important role in reducing nonpoint pollution and in improving the efficiency of point source control activities in the future. History offers a cautionary note, however. The idea of using effluent taxes to achieve compliance with ambient water quality standards is not new to the political arena or economic analysis. A review of this history is therefore instructive.

2. Effluent Tax Proposals: A Brief History

The Water Quality Act of 1965 (WQA) was the first major statutory attempt to address the nation's growing water quality problems. The Act proved to be a weak basis for enforcement authority, but did yield one major improvement: the development of ambient water quality standards. States were called upon to set their own standards and given flexibility to determine how standards would be met. The Act's major weakness was that it gave no concrete authority to force effluent reductions by specific polluters.[5] It was relatively straightforward to determine if ambient standards were being violated, but much more difficult to determine who was at fault.[6]

At the same time, however, economists were proposing effluent taxes as a policy that could both generate incentives to meet ambient quality targets and minimize the costs of doing so.[7] Moreover, proponents of effluent fees received a receptive hearing in the political arena. The Environmental Pollution Panel of the President's Science Advisory Committee recommended in 1965 "that careful study be given to tax-like systems in which all polluters would be subject to 'effluent charges' in proportion to their contribution to pollution .... Effluent charges have enhanced effects because individual polluters always have a prospect of financial gain from further reductions in their contribution to pollution."[8] In 1969, William Proxmire in the Senate and, in 1971, Lee Hamilton in the House introduced identical pieces of legislation calling for a national effluent charge.[9] Ultimately, these efforts went nowhere. But they indicate that 30 years ago the effluent tax concept was considered to be a serious policy alternative.

For this, credit is due to a set of economists and water quality engineers who were actively exploring the application of taxes to the problems of large, polluted watersheds. In the mid-1960s, large studies of the Delaware River Estuary were undertaken to assess, among other things, the desirability of using effluent charges to control pollutants. In 1967, Johnson reported that a "zoned" effluent charge program (where different tax levels were applied in different zones along the estuary) would cost half as much as a "uniform treatment" regulation.[10] Based on their own analysis of the Delaware Estuary, Kneese and Bower strongly advocated the use of charges for the same set of reasons: "The effluent charges procedure would have the advantage over other possible techniques of permitting each waste discharger to adjust in the most efficient way for his particular circumstances."[11] They went on to argue that systems of charges, in conjunction with basin-wide approaches to water quality management, "may properly be viewed as a central tool of water quality management. We feel that regional water quality management agencies should be provided with this tool."[12]

It is also interesting to note that these studies took a broad, regional approach to water quality problems and acknowledged the role of not just industrial sources, but nonpoint sources as well. In this respect, the work was particularly far-sighted. Unfortunately, the institutions necessary to implement regional approaches did not exist at that time.[13] Current water quality regulation, as exemplified by the TMDL program, is returning to watershed-level, multi-source analysis of water quality impairments. In the intervening years, however, water quality regulation took a more intermediate set of steps, focusing on direct quantity restrictions imposed on large point sources.

With the passage of the Federal Water Pollution Control Act (FWPCA) in 1972, the hope that effluent fees would be applied faded considerably. The FWPCA established the NPDES permitting system and its associated uniform treatment provisions. The government's choice of uniform technology-based standards was understandable, given prevailing frustrations with enforcement. But it effectively put an end to serious discussion of effluent fees as an alternative. The problem with the WQA lay in the implementation plans for ambient quality improvements. In particular, it was difficult to enforce specific reductions by specific polluters.[14] This failure generated a strong desire on the part of regulators and the concerned public to mandate facility-

specific reductions. The FWPCA's permit-generated uniform treatment standards directly addressed that desire. According to a history of the legislation:

> "Most of all, Federal officials regretted that the [WQA] made no provision for effluent standards. If federal water quality criteria included criteria for the quantity and quality of effluents and if implementation plans provided for the abatement of components of effluents, the task of enforcing standards would be greatly simplified. Federal officials believed that it would be easier to prove that discharges did not meet effluent standards than it would be to prove that they caused the receiving waters to fall below water quality standards."[15]

Treatment requirements imposed on individual firms were seen as the most direct response to pollution problems. In the climate of the early 1970s, and given the lack of regional institutions in place, the desire to minimize compliance costs and use taxes to meet ambient goals was less strongly felt. This is one explanation for the quantity-based regulatory system we have in place to this day. To understand some of the other explanations, it is necessary to describe the characteristics of a tax system in more detail.

Before doing so, mention should also be made of the European experience with effluent taxes. As early as the 1960s, France imposed water charges on certain industrial polluters and the Federal Republic of Germany passed an Effluent Charge Law in 1976.[16] In fact, early economic proponents of tax-based systems looked to the French and German experiments as strong evidence that taxes were practical institutionally and a hopeful example for other countries.[17] Subsequent analysis has led to a reevaluation of these systems. While the French and German governments continue to levy charges, the charge schemes act only in conjunction with treatment-based regulations, are primarily a revenue-raising instrument, and set taxes so low that they are unlikely in and of themselves to motivate significant abatement.[18] A particularly careful econometric study of the French program concluded that the French taxes are approximately one-half the level of measurable social damages.[19] Accordingly, the European experience's relevance as a "tax success story" is limited.[20] One notable exception is in the Netherlands. The Dutch program levies charges on both direct and indirect sources of

biochemical oxygen demand and heavy metals. The revenues are then used to subsidize improved treatment. What makes the Dutch program notable is simply that the fees are higher and have increased over time, and thus are capable of independently motivating reductions.[21] Econometric analysis suggests that the Dutch effluent fees, rather than treatment standards also in place in the Netherlands, are responsible for significant improvement in water quality.[22] Accordingly, the Dutch program stands as the single international example of a successful charge-based system.

3. 'First-Best' Taxation vs. the 'Charges and Standards' Approach

The efficient outcome of regulation is to have each source control emissions up to the point where the marginal costs of further controls exceed the marginal social benefits of greater pollution reductions. This definition is the easy part of policy design. The difficult part is designing policies that, when implemented in the real world, approximate efficient control behavior.

In theory, a tax-based policy and a command-and-control quantity standard can both achieve the efficient outcome.[23] With knowledge of the costs and benefits of pollution control, a regulator can simply require firms to engage in the efficient level of control. The efficient level of control can be directly mandated, say via a permit requiring a certain level of treatment. Alternatively, an effluent tax can be applied, with increases in the rate if control is inadequate and reductions if the tax is excessive. Both instruments can generate the efficient, "first-best" outcome.[24] Unfortunately, the equivalence of the two instruments, and their ability to generate the efficient outcome, break down in the face of real-world constraints. Perhaps the most important of these constraints is that regulators have limited information regarding both firm-specific control costs and the benefits arising from reduced emissions. When this informational constraint is taken into account, policy goals change.

For the first-best outcome to be achieved, different pollution sources must be held to source-specific levels of control or be assigned source-specific tax levels. This is true because the costs and benefits of control are unique to each facility. Technologies, locations, and other circumstances differ in important respects from one facility to the next. In practice, however, we cannot expect a regulator to easily determine these differences. It is very difficult to externally

measure, or even infer, firms' control costs. It is also difficult to determine the social benefits of controls, since the benefits (i.e., the damages avoided) are often diffuse and are typically not reflected in easily observable prices.[25] For these reasons, the efficient, first-best policy outcome is not the relevant benchmark. Instead, a more pragmatic question motivates the analysis of policy: namely, what is the best way to achieve a minimum level of ambient water quality in a waterbody? This is a "second-best" policy question because it abandons the goal of finding the most efficient outcome. Achieving ambient standards is a more limited and realistic goal. As noted earlier, states must establish, with federal oversight, surface water quality standards. Taking these standards as given, and ignoring the question of whether the standards themselves are efficient, we now turn to ways in which standards can be met at minimum cost.

This problem has been the focus of much of the economic literature on water quality. Because benefits are so difficult to measure, economists have long argued that the second-best problem is the most relevant one, at least as far as water quality policy is concerned.[26] In the words of Baumol and Oates, "It is hard to be sanguine about the availability in the foreseeable future of a comprehensive body of statistics reporting the marginal net damage of the various externality-generating activities in the economy."[27] In contrast to the first-best goal, the ambient standard goal does not require the regulator or policy analyst to know the social marginal benefits of individual firms' effluent controls. All that need be known is whether a given waterbody meets its quality standard.[28]

Regulators also lack good information about control costs. Ideally, a regulator would tailor taxes or quantity standards on the basis of facilities' control costs, so that facilities reduce pollution by different amounts. But this is impractical. In the words of Kneese and Schultze,

> "In practice, the need to tailor limits to each firm, and to consider for each the cost and effectiveness of all of the available alternatives for reducing pollution, would be an impossible task. There are up to 55,000 major sources of industrial water pollution alone. A regulatory agency cannot know the technological opportunities, the alternative raw materials, and the kinds of products available for every firm in every industry."[29]

Targeted fees or control standards tailored to the control costs and benefits of individual facilities—while efficient—are impractical from a real-world regulatory standpoint.

If taxes and standards cannot be targeted, what is the alternative? The alternative is uniform taxes and standards that apply to a range of facilities. Accordingly, economists have turned much of their attention to these more realistic alternatives. The literature compares two broad types of policy, the so-called "charges and standards" approach and a "uniform treatment" approach. Under the charges approach, a uniform tax is applied to a set of polluters, with the tax level set high enough to induce aggregate effluent reductions adequate to meet an ambient water quality standard.[30] Under the uniform treatment approach, all firms are required to reduce emissions by an equal percentage or amount, sufficient to meet an ambient standard. The uniform treatment policy roughly corresponds to the permit system currently in place in the United States. When these two, more practical policies are compared, taxes appear to be significantly preferable.[31]

Taxes are preferable because they are flexible in a way that mandated reductions are not. With a tax system, not all facilities have to reduce pollution by the same amount. Because facilities differ in their control costs, this flexibility is important. Under a tax scheme, high-control-cost firms abate less and low-control-cost firms abate more. In aggregate, this means that a given level of ambient water quality can be achieved more cheaply than if all firms abate the same amount.

TABLE 1

Units of pollution eliminated	Facility 1 marginal control cost	Facility 1 total control cost	Facility 2 marginal control cost	Facility 2 total control cost
1	10	10	20	20
2	20	30	40	60
3	30	60	60	120
4	40	100	80	200
5	50	150	100	300
6	60	210	120	420

As an example, assume that two facilities contribute to water pollution in a lake and that, for the lake's water quality to meet state standards, six units of pollution need to be eliminated. If the facilities' control costs are as described in Table 1, we can easily compare the tax and uniform treatment policies. A uniform treatment policy requires each firm to abate three units of pollution. The aggregate cost of complying with the uniform treatment policy is therefore $180: $60 for Firm 1, and $120 for Firm 2. Now consider an effluent tax equal to $45. With the tax, the two firms do not make the same abatement decisions. At that price, Firm 1 abates four units (because the marginal abatement cost of those units is less than the pollution price) and Firm 2 abates two units (for the same reason). In total, six units are abated, which meets the ambient goal. But note that the total cost of abatement, $160, is now lower.[32] This savings is the benefit of a tax mechanism. Also note that the regulator need know nothing about the firms' respective control costs to achieve this result. The tax can simply be iteratively raised (or lowered) until the water quality goal is met. It is in this sense that "effluent fees … tend to elicit the proper responses even in the absence of an omniscient regulatory agency."[33]

4. So Why Not Taxes?

Given their virtues, we now turn to the question of why taxes are not more widely applied in practice.[34] Broadly, there are two classes of explanation. First, taxes are politically unpopular, with opposition arising—for different reasons—from both the regulated and environmental communities. Second, the economists' argument that charges yield lower aggregate control costs than standards is not in fact always true. Under certain circumstances, a price-based approach can yield higher aggregate control costs than a uniform treatment approach. The reasons this is true are important to the design of any water quality regulation, and so we give them special attention in the following section. But, as a result, economists cannot say that charges are always more efficient than uniform treatment standards. This complication undermines the clarity of the policy prescription.

4.1 Political Objections

Political opposition to taxes as a control instrument comes from two quarters: the regulated firms themselves and environmental interests wary of the flexibility inherent in a price-based approach. To understand why regulated firms may oppose tax schemes, consider again Table 1. With a uniform treatment policy, as before, compliance costs are $60 for Firm 1 and $120 for Firm 2. With a tax policy, abatement costs are $100 for Firm 1 and $60 for Firm 2. But, in addition, both firms must pay the tax on all units of pollution they do not abate. The total compliance cost is therefore significantly greater. For example, Firm 1 will pay the $45 tax on the two units it doesn't abate, bringing its total compliance cost to $190 ($100+$90). Firm 2 will pay the tax on the 4 units it doesn't abate, bringing its total to $240 ($60+180). These tax revenues can be used, in principle, to offset the social cost of pollution the firms continue to emit.[35] Taxes shift pollution costs onto the polluters. This is socially desirable but can also be costly to firms if they cannot pass the tax on to consumers in the form of higher prices.[36] Standards can also deter (or disadvantage) the entry of new firms and facilities if new sources are held to higher standards than old sources, as they often are. From the standpoint of existing firms, this is an advantage.[37]

Environmentalists have resisted the use of charges on both ethical and pragmatic grounds. The ethical complaint stems from resistance to the flexibility inherent in the charge concept—not all firms have to abate the same amount. In the words of Bohm and Russell, "the polluter's ability to choose how to react to a charge, the heart of the economist's efficiency case,

is also the heart of the environmentalist's opposition."[38] Also, the idea of putting a price on pollution may be symbolically unattractive to some—despite the fact that it is the polluter who pays the price.

Pragmatic opposition arises from fears that a system of charges is administratively and legally more difficult to implement, and thus subject to more potential abuse by presumably well-connected polluters.[39] This critique argues that the legal basis for defining appropriate charges is weaker and the challenges associated with monitoring compliance are greater. As for taxes' legal basis, it is true that existing U.S. water quality regulations provide a more sound legal basis for uniform treatment standards than for charge-based systems. But that is because the regulations themselves are not designed to implement charges.[40] In principle, it is unclear why a charge-based system cannot be made legally sound—if the political will is present to do so. Others focus on the administrative challenge. In the words of one such critic, "Who is going to fix the charges, and how great are the chances that charges will be set higher or lower than some optimal level to satisfy the self-interest of particular interest groups?"[41] Of course, the same criticism can be leveled against the administrative procedures associated with setting appropriate treatment requirements. The difficulty is clearly present, but it is unclear why charge-setters would be more prone than standard-setters to ignore the public interest.[42]

A similar argument applies to the monitoring of uniform treatment and tax systems. Effluent charges require continuous monitoring so that the tax can be applied to actual discharges. Consider the following description of the monitoring problem: "These measurements are complicated not only by the features of invisibility and inherent 'fugitiveness' … but by the variability of discharges with production levels, equipment malfunctions and operator actions; by the imprecision of measurement devices and the discrete sampling techniques used in many such devices; and by the awkwardness involved in obtaining entry to a discharger's premises and setting up elaborate equipment in order to take the samples."[43] This seems to place tax-based systems at a disadvantage, since under current treatment-based approaches, continuous monitoring of effluent rarely occurs. Instead, the focus is on sporadic monitoring of installed treatment technology and effluent concentrations—which is easier to do. This draws the wrong conclusion, however. The fact that continuous monitoring rarely occurs under treatment-based systems is a significant weakness in the implementation of that approach.[44] Monitoring the simple installation of a treatment technology is certainly easier than continuous monitoring. But it is also far less effective. Ideally, treatment systems should also feature comprehensive monitoring to ensure that treatment standards are being met on a

continuous basis.[45] Again, the argument is not that effluent fee monitoring is easy, but that the monitoring challenge is no less significant under a treatment approach.

4.2 The 'Transport Problem'

When a pollutant is released, its impact on the environment depends on numerous factors. Pollutants deposited on land, such as pesticides and fertilizers, are carried into surface waters by runoff. Runoff is determined by climatic conditions, in particular rainfall, and by the geology of the region, including soil types and elevation gradients. Some of the pollution will degrade naturally, some will be deposited in soils and groundwater, and some will impair surface waters. The fate of pollutants deposited directly into surface waters is similarly complex. Once introduced, a pollutant's contribution to impairment is a function of the waterbody's assimilative capacity (which is itself a function of climatic conditions), salinity, acidity, and other localized chemical characteristics.[46] The hydrology of the waterbody affects the mixing and transport of the pollutant. Depending on the location of a release, and the nature of the pollutant, some pollutants will remain in-stream for long periods of time, while others will quickly degrade or be flushed from the system.

This means that similar releases in different geographic contexts can have markedly different environmental consequences.[47] In principle, these spatial relationships can be described in a systematic way. Hydrological systems can be characterized and described in formal terms. The better the description, the better are predictions of how a given release will effect a particular waterbody. Transport models describe these relationships.[48] In the words of one water systems analyst, "the relationship between the quality of water and the contiguous environment is essentially the domain of mathematical models."[49] Whether or not these models are practical and within the reach of contemporary science and regulatory budgets is an open question. Such models attempt to depict an inescapable reality, however—namely, that the social consequences of pollutant discharges depend on the geographic context of the discharge.

In the simplest terms, transport models divide the landscape into zones and define a matrix of transport coefficients associated with each zone. These coefficients take the form of parameters a_{ij}, where each a_{ij} describes the impact of a unit of pollution released in zone i on surface water in zone j.[50] With a complete matrix, the transport of pollutants within a larger geographic area, such as a watershed, can be holistically described.

TABLE 2

		Releases	
		Zone 1	Zone 2
Impacts	Zone 1	$a_{11} = 1$	$a_{21} = .4$
	Zone 2	$a_{12} = .2$	$a_{22} = 1$

A simple two-zone transport matrix might look like Table 2, where releases in a particular zone have a direct, one-to-one impact on that zone's water quality, but a lesser impact on the other zone's water quality.

A corollary implication of Table 2 is that units of pollution that are controlled (eliminated) in one zone will not yield a one-to-one improvement in ambient water quality in another zone. Pollution controlled in Zone 1 will directly improve Zone 1's water quality. The benefits will be less, however, in Zone 2.

How do transport problems affect the desirability and implementation of effluent charges? In a first-best world, the transport model is used to calculate the marginal social damages of a facility's pollution. A transport model is necessary because it describes the way in which actual pollution results in actual social damages in the broader landscape. But, clearly, the informational challenge posed by this activity is immense.[51] Even in a second-best world, where we seek a minimum-cost policy for achieving an ambient water quality standard, a transport model is necessary. The prescription in this case is to weight each firm's pollution by its impact on ambient water quality (perhaps in another zone). The least cost solution is arrived at only if each firm is induced to control its emissions to the point where marginal costs per weighted unit of pollution are equated across firms.[52] In practice, this means effluent charges that are not uniform across facilities, but are tailored to the transport characteristics of individual facilities.

Effluent tax schemes that account for the transport problem retain their desirability: namely, they lead to unambiguously lower control costs than treatment standards. Unfortunately, locational differences are quite difficult to take into account, and facility-specific taxes are administratively complex to implement.[53] According to the U.S. EPA, a key challenge facing agencies is "the lack of highly developed, scientifically sound approaches to identify problems in watersheds and to predict the results of potential control actions on water quality. While a wide variety of models are available, each comes with limitations on its use, applicability, and

predictive capabilities."[54] But these are precisely the kinds of models necessary to do effective tax targeting. So what about uniform charges? Can we still say they are preferable to uniform treatment? Unfortunately, the answer to this question is that "it depends." The unfortunate fact is that when transport phenomena are taken into account, tax schemes do not necessarily outperform even a crudely applied treatment standard approach.

The argument for charges over treatment standards is powerful and unambiguous until transport-related complexities are introduced. When they are, a potentially troubling ambiguity emerges. As noted by Rose-Ackerman in her 1973 critique of effluent charges: "When these complexities are recognized, it becomes apparent that, in any concrete application, an operational effluent charge may be a less efficient means of controlling pollution than a comparable non-market regulatory device."[55] Rose-Ackerman analyzed the realistic, second-best world where regulators lack facility-specific information about control costs and social damages—and therefore can apply only a uniform, nontargeted charge. In that world, effluent fees can result in higher aggregate control costs than uniform treatment rules.

TABLE 3

Units of pollution eliminated	Facility 1 marginal control cost	Facility 1 total control cost	Facility 2 marginal control cost	Facility 2 total control cost
1	1	1	5	5
2	2	3	10	15
3	3	6	15	30
4	4	10	20	50
5	5	15	25	75
6	6	21	30	105
7	7	28	35	140
8	8	36	40	180
9	9	45	45	225
10	10	55	50	275
11	11	66	55	330
12	12	78	60	390
13	13	91	65	455
14	14	105	70	525
15	15	120	75	600

An example illustrates this possibility. Table 3 is much like Table 1, showing the marginal and total costs of pollution control for two firms. In this example, however, we consider the different effects of the two firms' pollution on an impaired water segment. Referring to Table 2, assume that Firm 1 is in Zone 1, Firm 2 is in Zone 2, and Zone 2 has impaired water quality. Further assume that six units of ambient pollution need to be reduced in order to bring Zone 2 into compliance with the ambient standard. The transport matrix identifies

a constraint that must be satisfied.[56]   If q_1 and q_2 are the units controlled by firms 1 and 2, respectively, Zone 2's ambient water quality standard implies that

$a_{12}q_1 + a_{22}q_2 \geq 6$, or $(0.2)q_1 + q_2 \geq 6$.

Now consider the least-cost uniform treatment and uniform tax that satisfy the constraint. The least-cost uniform treatment standard requires each firm to reduce five units of pollution. If the level of abatement is any lower, the ambient standard will not be met.[57] The total cost of the uniform treatment requirement is $90 ($15 + $75). Now consider a uniform $15.01 tax on effluent. With that tax, Firm 1 abates 15 units and Firm 2 abates three units. This implies an ambient Zone 2 reduction of six units ((15)(0.2) + 3), which meets the goal. Any tax below $18 induces too little abatement. The total cost of the uniform tax is $150 ($120 + $30). Note the cost of the uniform tax is significantly higher than the cost of the uniform treatment standard.

Taxes do not necessarily outperform rigid treatment standards. This is the conclusion of a more complex—and realistic—model that depicts the realities of pollutant transport. More specifically, uniform taxes applied to nonuniform sources are not necessarily more efficient than treatment standards. It is very important to emphasize that targeted taxes— taxes based on individual facilities' effects on ambient water quality—do not suffer from this ambiguity. They remain clearly preferable to quantity-based standards. Uniformity is the source of the ambiguity. Tax uniformity is a deal with the devil. Uniformity makes implementation easier, but at a reduction in efficiency.[58] Under certain circumstances, the reduction in efficiency can erode the benefits of taxes to the point where even rigid quantity-based treatment standards are preferable. Empirical analysis confirms that this kind of outcome is a realistic possibility. An empirical analysis of alternative policies applied (again) to the Delaware Estuary showed that a uniform tax was more costly than a uniform treatment standard.[59]

This conclusion must be placed in its proper perspective, however. The example generated above, and the general class of cases where taxes underperform treatment standards, arise only in a special set of circumstances. What is distinctive about the above example is that the high-cost facility (Facility 2) is also the high-benefit facility, in the sense that its emissions reductions more effectively improve water quality. Facility 2's reductions generate one-for-one reductions in Zone 2's water pollution. Facility 1's reductions generate only one-fifth of these benefits. Two offsetting effects create this situation. On one hand, Facility 2 should abate less because it is the high-cost abater. On the other hand, Facility 2 should abate more because it's

the high-benefit abater. In the example, the two effects closely match and it is desirable for the two firms to abate similar amounts. This accounts for the uniform-treatment approach being the more efficient.[60]

A hybrid approach to effluent taxes can minimize the loss in efficiency that can arise from uniformity. In particular, taxes can be targeted not to specific facilities, but to classes of facilities that feature broadly similar control costs. And taxes can be targeted to different geographic zones. For example, a particular tax rate can be uniformly applied to large industrial facilities that release directly into a waterbody. A different tax can be applied to small sources that are more hydrologically isolated from water impairments. This kind of tax "zoning" can dramatically improve the performance of effluent charges, and at a reasonable implementation cost.[61]

With a zoned system, confidence in the relative efficiency of a tax approach is restored. And even economists who emphasize the danger of naively applying tax schemes do not conclude that, on balance, more rigid approaches are preferable.[62] There is simply too much theoretical and empirical evidence to suggest that significant efficiencies will arise with the use of a price-based policy. Empirical analyses of cost savings from incentive-based approaches (including both tax and trading schemes) typically find them to be significant.[63]

5. Doomed to Failure?

U.S. water quality regulation is undergoing a significant shift toward watershed-level, water-quality-driven controls on the widest range of sources, including nonpoint sources. Because nonpoint sources represent the most significant unaddressed challenge in the water quality area, the potential use of taxes as a means to control nonpoint pollution deserves more attention than has been given to it in this short review.[64]

The preceding discussion has focused on emissions taxes—i.e., taxes on pollution actually released. This presupposes that pollution can be measured, if imperfectly, at the point of release. That assumption becomes less and less reasonable as the focus shifts to nonpoint sources. After all, monitoring numerous small, and sometimes mobile, nonpoint sources looms as a large practical challenge. Accordingly, much analysis of nonpoint pollution control taxes focuses on the inputs to polluting activities rather than the outputs of that activity.[65] For example, it may be more practical to tax fertilizer and pesticide sales than to tax the runoff created by the use of such products.

Nonpoint sources also generate what are called "time varying discharges." As the term suggests, these discharges have an episodic, unpredictable nature. For example, nonpoint releases can spike as a result of storms that generate increased runoff and surface water flows. These spikes cannot be ignored or "averaged away" since they can have disproportionately significant impacts on environmental quality. And time varying discharges introduce uncertainty into ambient and source-specific monitoring protocols and increase the importance of continuous, rather than random, monitoring. They also confuse the relationship between control activities and ambient water quality outcomes. Nonpoint sources fear this confusion because it increases the regulatory risks they might face if called on to build in margins of safety adequate to insure against any episodic violation of standards. These characteristics do not necessarily disadvantage taxes relative to uniform approaches to nonpoint pollution. Monitorable treatment standards featuring margins of safety adequate to guard against discharge spikes will also be disproportionately costly to implement. Time varying discharges create barriers to nonpoint regulation generally, whether in the form of taxes or standards. They also suggest that "dynamic" pricing and permit programs are the relevant, ideal benchmarks against which to judge the performance of nonpoint regulatory programs.[66]

In spite of the challenges, however, nonpoint water quality taxes are a policy issue with enough virtues—for academic commentators at least—to warrant additional thought, debate, and consideration. Importantly, empirical analysis of nonpoint tax schemes is a focus of current literature.[67]

Nevertheless, the prospects for point and nonpoint source water quality taxes remain dim. Most clearly, sources want to avoid the additional costs imposed on them by pricing schemes.[68] Moreover, the explicit pricing of pollution, and the flexibility given to sources to respond to prices, wins few fans in the environmental community. This combination of source community and environmentalist opposition has been—and likely will be—politically fatal to the water quality tax concept. This is all the more true for nonpoint sources given the potency of agriculture as a lobbying force and the diffuse, numerous nature of urban and suburban sources.

Returning to the question posed in the title, water quality taxes may be doomed, but they remain a very good idea. The ability to innovate and adapt in response to a price signal, rather than a technological mandate, will always be a powerful motivation for market-based

approaches. From an environmental standpoint, pricing pollution does something that the existing regulatory system does not: namely, make polluters pay for their pollution so that the full social cost of polluting activities is reflected in the prices of the goods and services we purchase. Finally, the false dichotomy between "simple" command-and-control and "complex" pricing schemes should be resisted. Command-and-control policies present a wider range of monitoring and other administrative difficulties than is widely appreciated. Compared to current water quality regulation, water quality taxation is not orders of magnitude more difficult to implement and enforce. The challenges associated with them are simply more transparent.

EndNotes

[1] See other articles in this volume.

[2] For an overview of U.S. water quality regulation, see Freeman (2000).

[3] See U.S. EPA (1996). In common parlance, pollution from nonpoint sources is "runoff caused primarily by rainfall around activities that employ or cause pollutants," *United States v. Earth Sciences, Inc.,* 599 F.2d 368, 373 (10th Cir. 1979).

[4] For an overview, see Boyd (2000).

[5] Holmes (1979), at 190.

[6] See EPA v. California ex rel. State Water Resources Control Board, 426 U.S. 200 (1976) (addressing the difficulty of translating ambient water quality standards into standards that can control the conduct of specific polluters).

[7] For an overview of this early history, see Kneese and Schultze (1975), pp. 30–50. As early as 1964, Kneese (1964) had been urging the use of effluent taxes to cost-effectively improve water quality.

[8] *Restoring the Quality of Our Environment*, Report of the Environmental Pollution Panel, President's Science Advisory Committee, 1965, at 17 (cited in Kneese and Bower (1968) at 174).

[9] S. 3181, November 1969; H.R. 12304, December 1971.

[10] The study compared the costs of meeting a dissolved oxygen standard in the estuary. Johnson (1967).

[11] Kneese and Bower (1968) at 133.

[12] Id. at 141.

[13] See Kneese and Schultze (1975): "substantial economic-engineering research during the decade of the sixties made a compelling case for the systematic management of entire river basins using a wide array of technologies …. In the longer perspective—particularly in light of the relationship between the management of water quantity on the one hand and the need to develop programs for control of the residuals from nonpoint sources on the other—the failure to build institutions that could undertake efficient region-wide management was perhaps the most profound deficiency in the entire approach," at 44.

[14] Id.: "As a general proposition, enforcing the law against individual polluters was difficult, because it would have been hard to provide legally acceptable proof that the actions of a particular polluter had caused a deterioration of stream standards," at 39

[15] Holmes (1979) at 192.

[16] For histories of these programs, see Bower et al. (1981). Also see Kneese and Bower (1968).

[17] Brown and Johnson (1984).

[18] See Anderson (2001): "The charges apply to all entities discharging to surface waters, and are based on specific pollutants. However, the River Basin Agencies have not been free to set these charges, but have been subject to control from the Ministry of Finance … the charges have been too small in themselves to induce any control of pollution," at 12. Also see Glachant (1999) at 3.

[19] Thomas (1995) at 373.

[20] Bower, et al. (1981), discussing the French and German programs: "the effluent charges faced by individual activities are not set at levels meant to approximate marginal damages, to stimulate certain levels of treatment, or to produce desired levels of ambient water quality. Rather they are designed to raise a given amount of revenue," at 20.

[21] Barde and Smith (1997), citing a 120% increase in charge levels between 1975 and 1994, at 24; and Anderson (2001), citing figure that 71% of industrial investments for water pollution control in the Netherlands from 1970–1989 were supplied by means of the state water levy, at 16.

[22] Bressers (1988), summarizing his econometric analyses: "Taken together these analyses lead to the remarkable conclusion that the substantial reduction of pollution of Dutch industrial wastewater between 1975 and 1980 has been much more the result of a policy instrument, effluent charges, that was not officially designed for this purpose, than a result of the use of the policy instrument, direct regulation, specifically intended to achieve this objective," at 515.

[23] See Kneese and Bower (1968). Also, Weitzman (1974): "generally speaking it is neither easier nor harder to name the right prices than the right quantities because in principle exactly the same information is needed to correctly specify either," at 478.

[24] With full information, and no uncertainty, both taxes and quantity standards can yield the first-best outcome. See Kneese and Bower (1968): "If a regional authority had full information concerning all the costs associated with existing and potential waste generation and disposal, it could establish a set of effluent standards that would have the same effect on resource allocation as an ideal system of charges," at 135.

[25] Bohm and Russell (1985): "Any number of commentators in the early charges literature pointed out that … the very idea of any known and accepted damage function was more than economic knowledge could (perhaps ever) support," at 409.

[26] See Kneese and Bower (1968), responding to the less-than-ideal efficiency properties of a charges and standards approach: "It must be recognized, however, that certain costs of implementation that are ordinarily and properly neglected in reasoning about the character of ideal procedures cannot be neglected in practice …. A comparatively crude method that is generally correct in principle will often realize the major share of the gains that could be achieved by more complex and conceptually more satisfying techniques," at 251.

[27] Baumol and Oates (1971) at 43.

[28] The regulator levies "a uniform set of taxes which would in effect constitute a set of prices for the private use of social resources such as air and water. The taxes (or prices) would be selected so as to achieve specific acceptability standards rather than attempting to base them on the unknown value [of controls] or marginal net damages." Id. at 45.

[29] Kneese and Schultze (1975) at 88.

[30] A detailed description of this approach is provided in Baumol and Oates (1975).

[31] As will be described shortly, however, the devil is in the details. Taxes are unambiguously preferable only if potentially important real-world constraints are assumed away.

[32] Firm 1 abates four units at a total cost of $100, and Firm 2 abates two units at a total cost of $60.

[33] Kneese and Schultze (1975) at 88.

[34] Effluent fees are not entirely non-existent, but they tend to be applied at levels that raise revenue, but do not act as an incentive to reduce emissions. Several states impose "permit fees." Typically, however, the highest fees are less than $100,000 per facility per

year. As a point of comparison, effluent control costs routinely exceed $5 million a year at a large industrial facility. See U.S. EPA (2001(b)) at 36.

[35] Opposition to taxes can be reduced if the tax revenue is returned to the firms. The desirable incentive properties of the tax remain as long as the tax is returned in lump sum (independent of the level of control activity).

[36] It is socially desirable for a variety of reasons. First, efficient consumption is encouraged if product prices reflect the social costs of production. Taxes, unlike standards, accomplish this internalization of costs in prices. Second, the tax burden generates a stronger incentive for firms to innovate and thereby lower their abatement costs.

Taxes do not always make a firm worse off. In particular, if an industry's supply curve is flat—a condition associated, for example, with perfect competition—profits are unaffected by the imposition of a uniformly applied tax.

[37] Keohane et al. (1998): "Standards produce rents, which can be sustainable if coupled with sufficiently more stringent requirements for new sources. In contrast, auctioned permits and taxes require firms to pay not only abatement costs to reduce pollution, but also costs of polluting up to that level," at 363.

[38] Bohm and Russell (1985) at 419.

[39] See Bower et al (1981) citing "fear of a legal and administrative nightmare," at 18.

[40] Some argue that the existing framework could easily be adapted to a charge-type system. See Brown and Johnson (1984): "The applicant for an NPDES permit must provide EPA or the relevant state agency extensive and precise data on the quantity and content of the wastes to be discharged under the permit …. With this body of data already available it would not be technically difficult to graft an effluent charge system onto the present regime," at 961.

[41] Sax (1972) at 337.

[42] In fairness to Sax's argument, he advocates the empowerment of citizens as a check on administrative process, irrespective of the policy being implemented ("Putting legal power directly in the hands of the people who have a direct self-interest in maintaining threatened benefits seems to be one quite effective device for getting this job done." Id. at 339).

[43] See Bohm and Russell (1985) at 400.

[44] A series of government reports over the last two decades has been critical of the monitoring associated with the NPDES permit system. See U.S. General Accounting Office (1983); and U.S. EPA (2001(a)).

[45] Kneese and Schultze (1975): "The imposition of charges or taxes would require that effluents be metered at each outfall. But [treatment] regulations also call for metering," at 91. And again Bohm and Russell (1985): "… the monitoring problem is no harder if an emission charge is involved than if compliance with emission standards is the concern. Thus, criticisms of emission charges based on the claim that compliance is harder to monitor are incorrect when the alternatives are also concerned with limiting the discharge of residuals per unit time," at 416.

The systems do differ in one potentially important respect: the incentive to cheat. Under a treatment system, cheating firms avoid the costs of treatment. Under a price system, cheating firms potentially avoid both the treatment cost and the effluent fee.

[46] U.S. Geological Survey (1998).

[47] Kneese and Schultze (1975): "The impact on water quality from the wastes of any firm depends on the firm's location along the river basin and the hydrology of the stream," at 88.

[48] Schnoor (1996): "Regardless of how much monitoring data are available, it will always be desirable to have an estimate of chemical concentrations under different conditions, results for a future waste loading scenario, or estimates at an alternate site where field data do not exist. For all these reasons we need chemical fate and transport models, and we need models that are increasingly sophisticated in their chemistry, as we move toward site-specific water quality standards …," at 2.

[49] Thomann (1972): "Active links are required between, a) water use and water quality, b) water quality and the contiguous environment, c) the environment and the costs of controlling it, and d) the environment and the benefits achieved from control," at 5.

[50] See Thomann (1972).

[51] Bower et al. (1981): "This would require a very large and complex model including all relevant cost-of-discharge-reduction functions, characterizations of the regional

environment in its role as transporter, diluter, and transformer of residuals discharges, and the set of damage functions covering the region and categories of damages. Such a model would require that vast amounts of accurate data be available to the government agency seeking the optimal charge. Notice that because this optimal charge set will in general entail different unit charges for each discharger—not to mention each type of effluent discharged—the possibility of trial and error hunting for it through real-world experimentation cannot be taken seriously," at 16.

[52] See Kneese and Schultze (1975) at 88.

[53] Schnoor (1996): "We have found that every model based on experience elsewhere fails miserably in Iowa!" at 11.

[54] U.S. EPA (1992) at 4.

[55] Rose-Ackerman (1973) at 512.

[56] Recall that the discussion of the transport matrix also describes the effect of pollution controls on ambient water quality improvements.

[57] For example, a four-unit uniform treatment standard yields four units of Zone 2 abatement from Facility 2, but only 0.8 from Facility 1 (i.e., four times 0.2). The total ambient reduction is thus only 4.8 units.

[58] Brown and Johnson (1984): "Simplifying eventually involves making charges and standards and other debatable components of policy more uniform by aggregating and averaging. It saves transactions and political costs, ultimately at the expense of efficiency," at 950.

[59] Spofford (1983).

[60] This is the reason Spofford's empirical analysis found uniform treatment to be preferable in the Delaware Estuary. High marginal cost sources were found to have large impacts on ambient concentrations. Note, though, that the same study found huge cost savings associated with more targeted taxes.

[61] See Tietenberg (1974) for a more detailed treatment of this kind of proposal. Also see Baumol and Oates (1975): "A device that may sometimes work reasonably well involves the establishment of different zones, based on concentration of population and current pollution levels, with different tax rates imposed in different zones," at 146.

[62] See Rose-Ackerman (1973): "We have emphasized the weaknesses of a 'market solution' in our analysis of the effluent charge scheme only to counteract the common professional tendency to criticize non-market methods of resolving the externalities problem without undertaking a similar careful scrutiny of the economist's favored strategy," at 527.

[63] U.S. EPA (2001(b)), at 26.

[64] For an overview of the large literature on nonpoint source control (including analysis of taxes), see Shortle and Horan (2001).

[65] Griffin and Bromley (1982) and Segerson (1988).

[66] See Eheart et al. (1987).

[67] As an example, see Wu and Babcock (2001).

[68] Tax revenues can in principle be returned to sources in ways that preserve the desirable incentive properties of a price-based system and at least partially offset sources' added distributional burden.

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