Draft - June 23, 2001

Toward a Total-Cost Approach to Environmental Instrument Choice

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1. Introduction

Much of the extensive theoretical literature on the efficiency of instruments for environmental regulation is predicated on the presumption of *ex ante* uncertainty about the *ex post* costs and benefits of policy choice. Beginning with Weitzman (1974), the literature has centered on the factors that might lead regulators to favor a price-based over a quantity-based instrument, or vice versa.[1] Although Weitzman did not prescribe exact types of price or quantity instruments, many scholars see the issue as a binary choice problem pitting a price-based effluent tax regime against a quantity-based regime of tradeable emissions permits The comparison of only these two alternatives reflects a normative presumption that only such "economic" instruments have any possibility of producing an efficient outcome. Other potential alternatives, such as non-tradable emissions quotas or more general taxation arrangements (such as input or production taxes) are ruled out as inherently inefficient (Tietenberg 1985; Stewart 1996) and even anti-democratic (Ackerman and Stewart 1985; Stewart 1992; Sunstein 1997).

Moreover, most of the literature relies on an important but unwarranted assumption: that cost and benefit functions, although they may be subject to uncertainty, are identical regardless of the regime that is chosen; that is, price and quota systems are assumed to face the same cost and benefit curves with the same expected values. Most crucially, the models assume that no regime will be subject to greater or lesser *uncertainty* than another. In other words, the variance is

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[1] Some of the major contributions to this literature besides Weitzman's seminal piece include: Adar & Griffin (1976); Fishelson (1976); Portney (1990); Stavins (1996); Watson & Ridker (1984); Yohe (1978).

assumed to be *in*variant with the choice of regulatory regime. Under these assumptions, virtually all existing economic theories of environmental policy suggest that instrument choice should be determined simply by the relative elasticities of the curves.

Environmental instrument choice in the real world is, however, more complicated than existing theories suppose because the assumptions on which those theories are based do not always obtain. In the real world, the costs of administering – that is, monitoring and enforcing – one regime might be quite different from the costs of administering another regime. Technological and institutional factors may make one regime not just *more* costly but infeasible, in which case the most efficient instrument must be some alternative that appears inferior from the perspective of theories that rely on the above-mentioned assumptions. These considerations apply not only to comparisons of effluent tax regimes and tradeable permit programs but also to comparisons between "economic" instruments generally (including both taxes and tradeable permits) and command-and-control regulations and general Pigovian taxes. Though much of the theoretical literature predicts greater efficiency from the former, the theory is incomplete.[2] A more complete theory, as well as experience, demonstrate that in some instances economic instruments are *less* efficient than the traditional alternatives.

This is a positive, rather than normative, proposition. In some cases economic instruments are clearly more efficient than traditional regulatory regimes. But in other instances, for example where efficient market institutions are absent, economic instruments will not efficiently or effectively attain exogenously determined pollution-reduction goals (Cole & Grossman 1999).

The key factor in determining the comparative efficiency of alternative approaches to environmental protection are transaction costs – specifically, for purposes of this paper, measuring, monitoring, and enforcement costs. Much of the theoretical literature comparing environmental instruments assumes away these costs as insignificant. As Russell et al. (1986, p. 3) put it, economists tend to assume "perfect (and incidentally, costless) monitoring." Or they assume that measuring and monitoring costs are constant across instruments, so that those costs do not affect the analysis. These assumptions conflict with numerous studies that find sizeable differentials in measuring or monitoring costs from one

[2] There has been some theoretical work showing the economic instruments may not always be the most efficient choice. Hahn and Axtell (1995), for example, demonstrate that even in theory, if monitoring is assumed to be imperfect, it is not clear that market-based approaches to environmental protection will entail lower total costs than approaches that utilize technological standards or Pigovian taxation. More generally, however, theory, with its simplifying assumptions about administrative costs, tends to strongly favor economic instruments.

environmental protection instrument to another, depending on technological and institutional circumstances (Office of Technology Assessment 1995; Driesen 1998; Anderson et al. 1977; Solow 1971).

There are, indeed, circumstances in which technology-based command-and-control regulations or simple taxation schemes are less costly to monitor and measure than either effluent taxes or permit-based pollution quotas. This monitoring-cost differential may be so great in some cases as to more than offset the compliance-cost differential that typically favors such "economic" instruments. In other words, while effluent taxes or tradeable pollution permits may reduce the *compliance* costs of pollution control, they may in some cases entail higher *total* costs because of their higher costs of monitoring.

This paper offers a theoretical framework to explain why cost-curves will differ depending on regime choice, and applies that framework to a current regulatory effort. The model is elaborated in the following section. Section 3, then, discusses its implications for environmental policy generally, and in particular for the Kyoto Protocol to the United Nations Framework Convention on Climate Change, which would institutionalize a tradeable permitting approach to greenhouse gas emissions reduction. The framework described in this paper provides reason to question whether tradeable permitting is the most efficient approach to reducing greenhouse gas emissions internationally, considering the technological constraints and institutional defects that plague many (if not most) of the parties to the convention.

2. The Costs and Benefits of Regulatory Instruments: Theoretical Considerations

All considerations of the economic efficiency of regulatory instruments begin, and actually end, with the basic condition that to maximize social welfare, pollution control should be expanded until the marginal social benefit (MSB) of control equals the marginal social cost (MSC). In a world of complete information this would be easy to formulate, and the lowest cost means of achieving it would be straightforward. In fact, in a world of complete information the form of regulation should not matter; the lowest cost would always be achieved (see Coase 1960). However, in the real world of incomplete information the efficiency condition is difficult to achieve. As many have noted, there is always going to be some degree of *ex ante* uncertainty about the price and quantity of pollution control that will satisfy the basic efficiency condition, MSB=MSC. Weitzman (1974, p. 480) observed that in regulatory cases uncertainty arises because of an "information gap." Regulators and engineers can only estimate around random variables that are more or less difficult to quantify; consequently, the ideal level of pollution control that will equate marginal social benefit with cost (and so maximize social welfare) simply cannot be known at the time the regulatory regime is designed and implemented. This would be true even if the universe of polluters were small; complete information about costs and benefits could only be roughly estimated *ex ante*.[3]

In general, both costs and benefits are subject to this information gap (Stavins 1996). The *source* of this gap is, however, an important factor that is often neglected. With respect to environmental pollution, the main impediments to complete information are the difficulty and costliness of (1) reliably measuring pollution discharges (and the short- and long-term effects of those discharges), and (2) monitoring polluter behavior. There may also be considerable uncertainty – and so uncertainty as to costs – with respect to enforcement. Economic models typically assume reliable, low-cost enforcement as it currently exists in polities like the United States. In some political systems, however, enforcement is irregular at best, subject to influence or corruption, and dependent on other factors that lower the reliability of enforcement and raise costs to society. Put more generally, the principal reasons for uncertainty are the transaction costs associated with the regulatory process.

High monitoring and enforcement costs may also be related to technological constraints. It can be very difficult and costly to measure both the amount of effluent that a polluter emits and the environmental damage that it causes. This may be especially problematic when regulators require continuous, real-time emissions measurement. In a quota-based system of tradeable pollution permits, if data cannot be reliably gathered on an ongoing basis, it may be impossible for regulators to know whether firms are adhering to their quotas.[4] Moreover, in the absence of monitoring it is unlikely than any market for permits would exist because there would be no incentive for owning them. Quotas (whether marketable or not) can only be effective if they can be enforceable. And they are only enforceable if the regulator can monitor compliance. Who would bother to comply with a quota that the authorties could not enforce because they had no way of monitoring compliance? Under this circumstance, the economic value of quotas would be zero. And they would be completely ineffective as a pollution-control device.

Institutional factors may also raise the costs (or reduce the benefits) of pollution-control efforts. If laws are enforced only randomly, profit maximizing

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[3] This paper assumes, at least with respect to theory, that *ex post* costs and benefits are known. This is not necessarily the case. For example, the EPA could only produce a very wide range of estimates in its attempts to quantify the net benefits that have been realized from the Clean Air Act of 1970. See Cole and Grossman (1999) for a discussion.

[4] Cole and Grossman (1999) argue that it was the availability of cost-effective continuous emissions monitoring technologies that made tradeable permitting a feasible, and relatively efficient, policy choice for controlling sulfur dioxide emissions in the United States, under the 1990 Clean Air Act Amendments.

firms will weigh the expected cost of compliance against the expected cost of non-compliance. If the probabilities of enforcement are low enough, or the penalties for non-compliance are small, there will be substantial non-compliance, raising the social costs from additional pollution damage.[5] This is the case regardless of the regulatory instrument chosen. However, other institutional factors, such as weak or nonexistent market institutions, may raise the costs of controlling pollution with some instruments more than others. If market prices are, for example, inaccurate indicators of value, it may be very difficult to determine the efficient level for effluent taxes. Or if polluters are subject to soft budget constraints, so that their continued existence does not depend on profitability in the market (see Kornai 1986), *no* form of price regulation is likely to affect pollution levels.[6] Similarly, if trading and contracting are generally costly and uncertain, the utility of tradeable permit programs for reducing compliance costs is questionable, even if monitoring technology is adequate and cost-effective.

For this analysis, we assume a social-cost function comprised of three components: (1) compliance costs, which include primarily abatement costs for regulated polluters; (2) administrative costs, which include costs of measuring, monitoring, and enforcing regulations for government; and (3) the cost of damage stemming from the absence of pollution control. The latter category includes the costs of coping with the spillover affects of pollution that will be associated with the failure to comply, measure, or monitor accurately, as well as the cost of residual pollution that is accepted by society as an efficient by-product of production.

We also assume with Watson and Ridker (1984) that the marginal cost and benefit functions are non-linear. This assumption is warranted because (1) total control costs – the sum of compliance costs and administrative costs – tend to rise at a faster rate as society attempts to gain higher levels of pollution control; and (2) social benefits tend to fall off more quickly at high levels than they do at moderate levels of abatement. The assumption carries an additional implication that forecast errors are multiplicative, not additive as most theoretical analyses

[5]This paper looks at the broad costs and benefits of a regulatory regime. From the firm standpoint, the amount they are willing to spend on regulatory compliance will be determined by the expected penalty from non-compliance. If indeed the probability of enforcement is low, then the marginal penalty of noncompliance falls, and the willingness to incur compliance costs falls as well (see Harford 1978; Hahn & Axtell 1995.)

[6] This proposition is strongly supported by evidence from former communist countries, such as Poland, which instituted numerous environmental taxes, all of which failed to affect pollution emissions because of endemic soft budget constraints. Central planners nearly always compensated state-owned enterprises for any environmental fees and fines incurred. Even when they did not, the taxes did not affect polluting behavior because, ultimately, profits or losses had little bearing on enterprise survival (see Cole 1998, pp. 146-53).

have assumed. Such multiplicative forecast errors seem particularly likely to occur when there are measurement or enforcement problems. As measurement fails, for example, enforcement becomes more costly and random, the advantage to firms of noncompliance grows, and damage costs begin to expand rapidly.

An important theoretical issue arises, however, once curves are assumed to be non-linear. In Weitzman's (1974) basic model, the choice between a price instrument and a quantity instrument depended on the relative elasticities of the cost and benefit curves. By assuming non-linearity, the instrument likely to maximize social welfare, by producing the efficient level of pollution abatement, could change depending on where regulators believe the marginal benefit and cost curves intersect. Even from the perspective of standard analysis, then, non-linearity can alter the policy equation.

Costs and benefits are both subject to uncertainty, and so can only be estimated within a range. Probabilities are described by a distribution function, which assigns a positive probability to all outcomes within the range. The variance of this range is assumed to increase as a greater degree of control is desired. Thus, at low levels of control the degree of uncertainty is relatively less than it is at high levels of control.

The variance would appear especially sensitive to the quality and quantity of monitoring and measurement, and the more an instrument relies on monitoring and measurement for its success, the greater the variance is likely to be. It is axiomatic that the greater the difficulty in measurement, the greater the potential range of error. This error can either increase or decrease costs.

In fact, measurement problems may increase either or both compliance and damage costs – as too much control is demanded or as too much damage ensues. Consider a situation, for example, in which real-time measurement of effluent discharges is costly because cost-effective monitoring technology is not available.[7] As a consequence, firms and/or regulators must increase labor hours or other inputs to achieve more reliable measurement and consistent monitoring of discharges (assuming that labor and other inputs can serve as substitutes for unavailable technology), adding to marginal compliance and/or administrative costs. But the reality of measurement error also means that there is a positive probability of larger (or smaller) marginal damage costs. As the need for measurement increases, the probability of larger and larger error, and compounding of errors, also increases. Consequently, the range of cost estimates could expand quickly and dramatically as larger and larger increments of control are demanded.

For simplicity's sake, it will be assumed in all figures that the marginal benefit

[7] This situation obtained in the US with respect to the administration of the Clean Air Act in the 1970s (Cole & Grossman 1999).

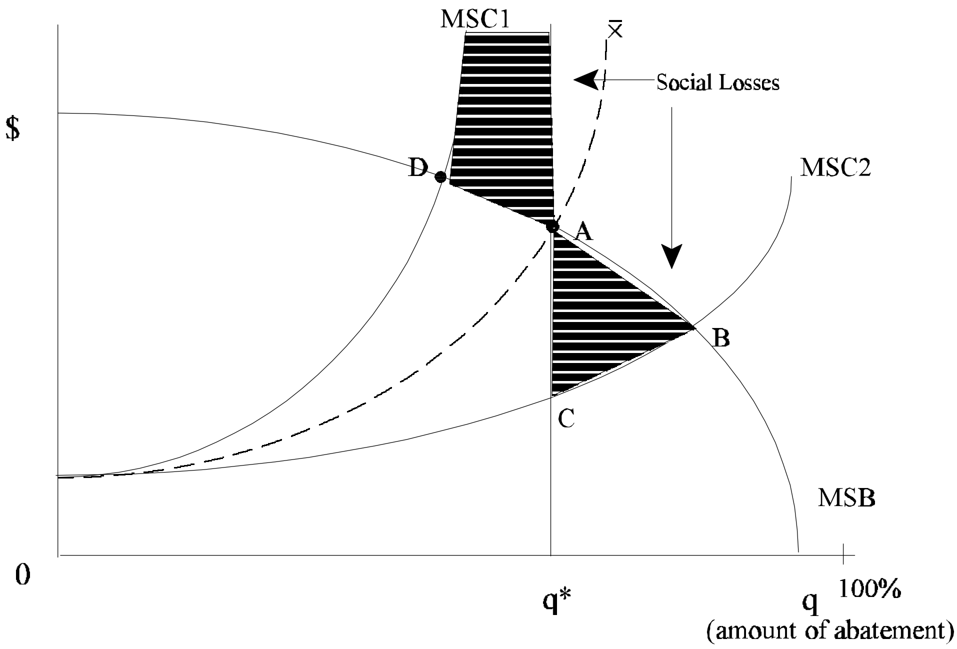

Figure 1. Quota Instrument X

curve for all instruments is certain but the marginal cost curve is uncertain, and that regulators always seek to maximize net social benefits. In Figures 1 and 2, the choice will be limited to two quota-based regulatory instruments, X and Y, which correspond to a tradeable permit regime and a nontradeable quota or command-and-control regime. For both instruments, there are *ex ante* uncertainties about costs because of measurement, monitoring, and enforcement problems.

We assume that the regulatory agency must choose both an instrument (either X or Y) and specify a quota limit, q*, expected to achieve the regulatory goal. Given uncertainty we assume that regulators initially set the quota at the point where the marginal social benefit curve intersects the mean of the range of the marginal social cost curves ($\overline{x}$), specified at point A on Figure 1. However, since all points within the range including the *extrema* are possible, the *ex ante* estimate of social losses would include the sum of the expected losses in each state. If actual costs prove to be lower than the mean, so that it is shown *ex post* that the marginal cost curve MSC2 is correct and the truly efficient point is where MSB=MSC (at B), then the social loss is described by the area, ABC, representing unrealized efficient gains. *Ex ante* regulators would value that possible loss at B at its expected value: equal to the area ABC multiplied by the probability that MSC = MSB at B.

If, however, the mean is well below the *ex post* cost curve, and MSC1 is the correct representation of marginal costs (and the efficient point is at D), then any

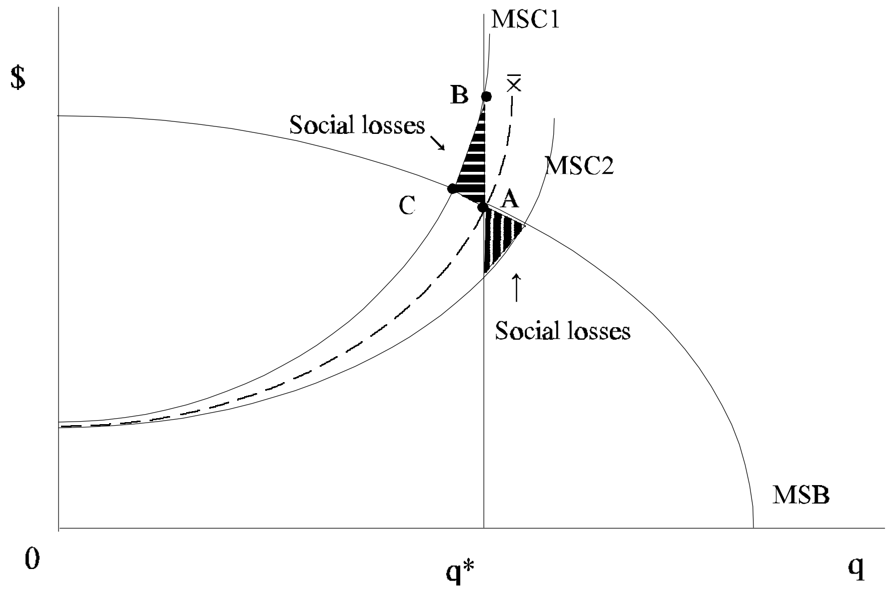

Figure 2. **Quota Instrument Y**

attempt to meet q* will be very costly, if it is attainable at any finite price. Net social costs would be prohibitively high. And regulators when estimating *ex ante* the efficiency of alternative instruments, must include the expected value of the shaded area on the graph in computing the expected social cost of using Instrument X.[8]

Figure 2 shows curves for the alternative non-tradeable quota-based instrument, Instrument Y. There is greater *ex ante* certainty about the cost of this instrument because it is cheaper and easier to monitor and measure. This reflects the fact that monitoring compliance with technology-based command-and-control instruments is relatively straightforward; regulators need only to ensure that the technology is installed and operating. As Maloney and Yandle (1984, p. 247) have noted, the installation and operation of the technology itself becomes the standard of compliance; actual emission rates need not be known, and therefore need not be measured. Consequently, monitoring for technology-based command-and-control regulations tends to be less expensive than monitoring for tradeable permitting programs, where regulators must be able to monitor actual emissions

[8] Consider a mathematical example: Let's say that there is a probability of 0.5 that the efficient equilibrium (MSB=MSC) will be D, and a probability of 0.5 that the equilibriumwill be at point B. Note that the mean is at A even though the probability that MSC=MSB is at A = 0. However, the expected loss (L) will be E(L)=0.5 (area ABC) + 0.5 (area between MSC1 and q*). Since the last area is infinite, the loss function cannot even be calculated.

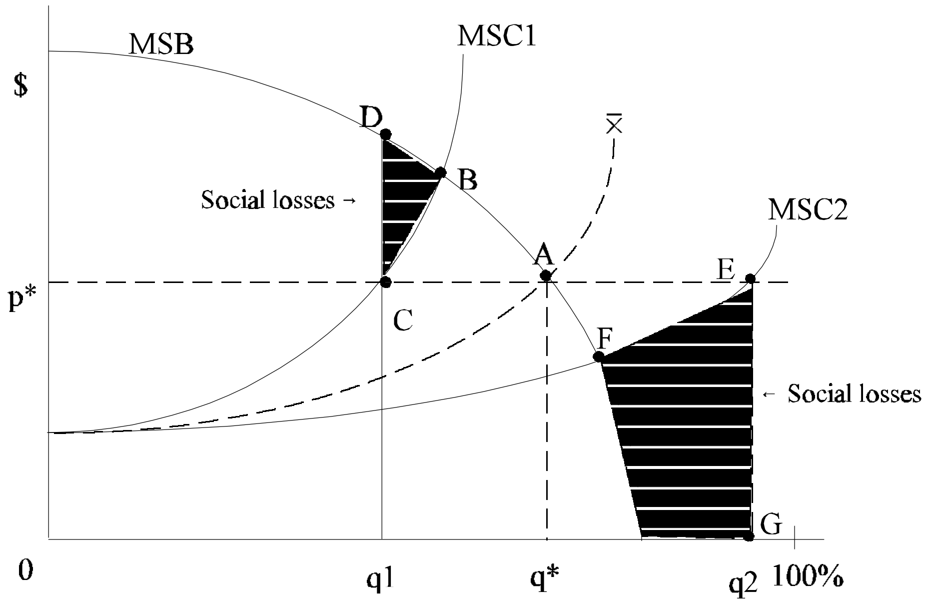

Figure 3. **Tax Instrument V**

to enforce compliance, at any given time, with changeable quotas. In the early 1970s, for example, regulators managed to inspect, at some finite cost, every major stationary source of air pollution in Southern California once each month to ensure that required pollution-control technologies were properly installed and operating (Willick and Windle 1973). Because of then-existing technological constraints, however, they could not have continuously monitored individual emissions at any finite cost, to ensure compliance with tradeable permit quotas (Cole and Grossman 1999, pp. 920-1).

Technology-based command-and-control regimes usually entail higher *compliance* costs than tradeable permit programs because polluters with high costs of control are required to install the same equipment, reducing emissions by the same amount, as polluters with low costs of control. Thus, the mean of the range of marginal control costs is actually higher in Figure 2 than it was in Figure 1. The quota is set where MSB equals the mean of MSC, and therefore q* represents a lower level of pollution control than we saw in Figure 1. The variance is, however, considerably smaller in Figure 2 than in Figure 1, and so too are the expected losses. Moreover, even if the actual marginal cost curve is at its highest level, MSC1, q* will be attainable, with the loss represented by the shaded area, ABC.

As these graphs reveal, it may be well be the case that Instrument X (represented in Figure 1) is *potentially* a more efficient instrument than Instrument Y (represented in Figure 2), but only if the range of costs in the first case can be narrowed. Otherwise, the uncertain (and probably higher) expected monitoring

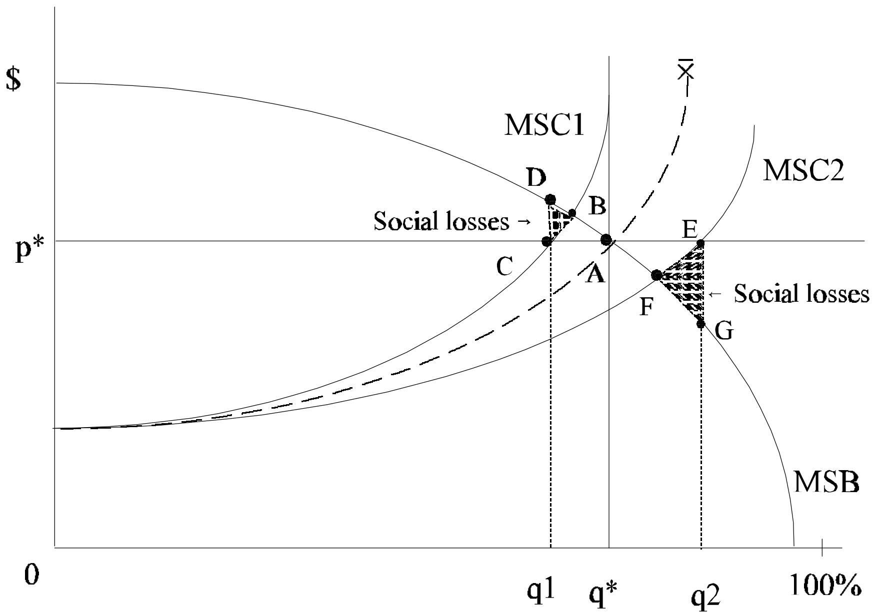

Figure 4. **A Tax May Be More Efficient Than a Quota**

costs of Instrument X may more than offset its compliance-cost efficiency advantage. In that case, Instrument Y – the nontradeable quota – would be more efficient, all things considered, than Instrument X – the tradeable quota. Instrument Y would maximize net social benefits.

The same reasoning may make a particular price instrument more efficient than another. Suppose, for example, society has a choice of two price options: an effluent tax on emissions levels (Instrument V) or an output tax on a polluting industry (Instrument W). Clearly, if firms have differential costs of pollution control, the latter tax will entail higher *compliance* costs. If, however, there is great *ex ante* uncertainty about emissions levels, or if enforcement of emissions limitations is more costly, the output tax may prove easier to monitor and measure. If so, it would minimize expected social losses, and so constitute the most efficient instrument in terms of *total* costs.[9]

This is illustrated in Figure 3. Here regulators set a price target (p*) which

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[9] An output tax would raise output prices and so lower total output. Unlike an efficient effluent tax, however, an efficient output tax should not create any incentive for regulated firms to reduce pollution emissions; to the contrary, it would create a disincentive to invest in emissions reduction technology because emissions reduction will not save regulated firms on taxes (unless the output tax is combined with tax deductions for environmental investments). However, if output taxes are adjusted to account for environmental damage costs, such instruments still would satisfy the basic Pigovian requirement that externalized costs be internalized.

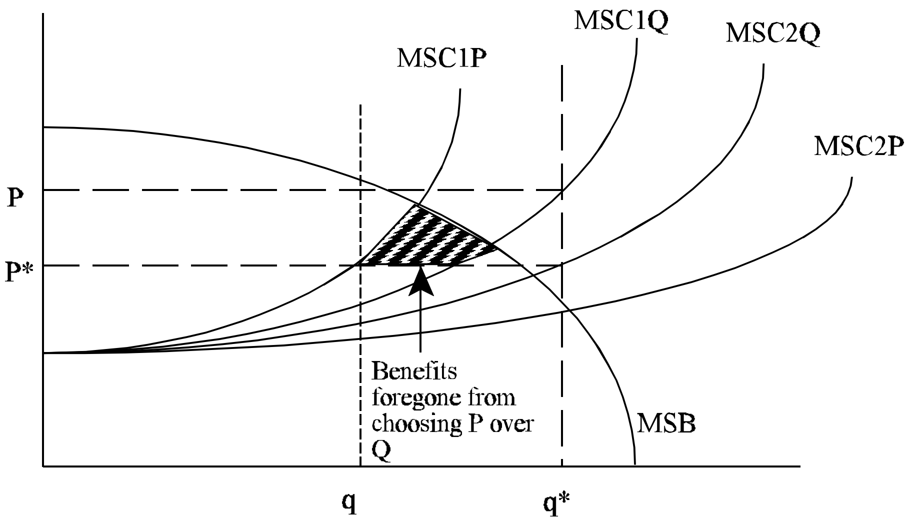

Figure 5. **A Quota May Be More Efficient Than a Tax**

is assumed to equate MSB with MSC at an efficient level of control (q) shown at point A, again given in the figure as the mean of the range of estimated MSC. The tax is set to achieve that. Where the real private cost is higher than expected, however, a tax will lead to a real incremental cost of abatement that will produce the level of control at q1. Given the full social curve, MSC1, the efficient level should actually be at B where MSB=MSC. The taxed price is too low, and social losses will be equal to the area of BCD. If MSC2 is closer to the actual level of cost, then the tax will be too high, and social losses from overinvestment in pollution control, EFG, will obtain. The full value of social costs must include the expected value of both of these areas, and it must be factored into the expected cost of the effluent program. Moreover, as before, expected social costs might well be lower with a different tax instrument – one with a higher mean but a smaller variance. This second tax instrument, though less efficient in world of low transactions costs, would be a more efficient alternative, as shown in Figure 4.

An effluent tax may raise another problem. With Instrument V and marginal cost schedule MSC1, when price is set a p* the efficient level of pollution control should be reached at B; but since p=MSC at C, there will be no incentive to abate further then q1. But often a tax instrument is intended to produce, like a quota, a specific or, at least, an approximate level of abatement that regulators deem likely to improve public welfare. Assuming Instrument V and MSC1, even if the "efficient" level at B is reached, regulators will remain well short of the level of abatement they would have anticipated around the mean of the range. Indeed, if the other instrument, W, is chosen, the level of abatement will be closer to the expected abatement level, no matter where the actual cost falls within the range.

Thus, the alternative instrument (W), which has no positive probability of abatement less than q1 (Figure 4), may be preferred regardless of the fact that there will also be some positive probability that Instrument V would provide At the outset, the choice will be limited two quota-based regulatory instruments, X and Y, which correspond to a tradeable permit regime and a nontradeable quota more abatement at lower cost.[10]

Finally, the analysis can be extended to show instances, as in Figure 5, in which a *quota* instrument of one type may be more efficient than a *price* instrument (or vice versa). Consider the case of effluent taxes, where a price is set equal to p* as in Figure 3. Because of measurement and enforcement difficulties, the range of costs is considerable, and marginal costs are described by MSC1P and MSC2P. Again, the social costs must include the expected value of the social losses. Moreover, even if the expected mean of marginal costs of the second instrument, say a command-and-control quota, (described by MSC1Q and MSC2Q)is greater than the mean for the tax instrument, the smaller variance of the latter may well make it the more efficient choice. Again, lower *monitoring* costs may mean lower *total* costs, even if *compliance* costs are higher. Further, if MSC1P and MSC1Q were both to obtain, and the price instrument would be at p*,q and the quota at p, q*, there would be significant foregone social benefits by choosing the former (tax) over the latter (command-and-control) regime.

This analysis is, of course, static. There is no reason to expect that circumstances would remain the same over time; technological improvements and changing institutional factors could well alter relative monitoring and compliance costs, and favor a change in regime. When the US Clean Air Act was first enacted in 1970, for example, Congress could not have relied on effluent taxes, tradeable permits, or any other regime that depended on low-cost, precise, and continuous emissions monitoring because the necessary technology did not then exist. By the time the Clean Air Act was amended in 1990, however, technological improvements – particularly the innovation of cost-effective continuous emissions monitoring systems (along with certain institutional changes, such as the Environmental Protection Agency's increasing economic expertise) – made emissions trading a lower cost alternative to command-and-control for *some* combinations of pollutants and sources.[11]

Even today the United States does not have the technological capability to cost-effectively monitor all pollutants from all sources. This continues to limit the utility of tradeable permit and effluent tax schemes as alternatives to technology-based command-and-control regulations. Consider, for example, the problem of

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[10] This might depend on social risk preferences.

[11] For a study of the historical evolution of air pollution policy under the Clean Air Act, see Cole and Grossman (1999).

controlling nitrogen oxide emissions from cars and trucks. It is beyond existing technological capability to continuously and cost-effectively monitor the emissions of each individual car and truck. Although emissions trading and effluent charges have succeeded in controlling emissions of some pollutants, including nitrogen oxides, from certain kinds of stationary sources such as coal-fired electric power plants, in this instance some kind of industry-wide technology-based standard would almost certainly entail lower monitoring costs, and lower total costs, than a tradeable quota system, according to which each car driver is assigned a certain level of allowable emissions.

3. Implications for Policy Making

The consensus in the literature favoring so-called "economic instruments" – effluent taxes and tradeable quotas – for environmental protection is based on studies that compare only the compliance or abatement costs of alternative instruments. They do not compare the *total* costs, which are the sum of compliance/abatement costs, administrative (including monitoring) costs, and residual pollution costs. Consequently, they provide an insufficient basis for concluding that, in any specific case or across the general run of cases, effluent taxes or tradeable quotas are preferable to non-tradeable quotas or Pigovian taxes. They may well be more efficient in many cases, but the studies are inconclusive because they fail to account for monitoring and other administrative costs, which may in some cases make traditional regulatory instruments preferable.

Despite this, the consensus favoring "economic instruments" has greatly influenced enviromental policy making in recent years, both domestically and internationally. To the extent environmental protection policies are premised on the misperception that economic instruments tend to entail lower total costs than traditional regulatory approaches, those policies are not well founded. They may, consequently, have negative environmental and economic consequences.

Consider, for example, the 1997 Kyoto Protocol on global greenhouse gas emissions. The parties to the Protocol decided, with very little deliberation (under pressure from the American delegation), to rely on tradeable quotas as a primary mechanism for achieving the Protocol's emissions-reduction targets. The ostensible goal was to minimize the costs of achieving those targets.

The parties to the Kyoto Protocol were certainly right to think that emissions trading would ensure lower compliance/abatement costs. But as we demonstrated in Section 2, lower compliance/abatement costs do not necessarily mean lower *total* costs. In some cases, abatement cost savings may be offset (or more than offset) by higher monitoring costs.[12] As noted earlier, the costs of monitoring individual, point-source emissions to ensure compliance with changeable, tradeable quotas are likely to exceed the costs of monitoring to ensure compliance with technology-based non-tradeable quotas. Simply put, it is cheaper and easier to check whether a scrubber is installed and operating than to continually measure actual emissions ensure that each plant is in compliance with changeable, tradeable quotas at each and every point in time (see, for example, Maloney and Yandle 1984, pp. 246-7). The question becomes whether those higher monitoring costs are at least offset by the abatement cost savings that tradeable quotas provide. In the absence of any comparison of the relative costs of compliance, administration, *and* residual pollution, the parties to the Kyoto Protocol had insufficient basis for concluding that emissions trading would achieve the Protocol's goals at lower *total* cost than alternatives, including technology-based non-tradeable quotas.[13]

The Kyoto Protocol provides only some general guidelines for emissions accounting, verification, and reporting. It directs signatories to use standard methods to measure and estimate their national greenhouse gas emissions, and it includes some general provisions regarding technology transfers, which could potentially be used to ameliorate monitoring deficiencies. According to critics such as Breidenich et al. (1998, pp. 324, 327), however, these guidelines are inadequate to ensure compliance. Moreover, as Tietenberg et al. (1999, p. 51) have cautioned, "[w]ithout the appropriate administrative structures and procedures, a tradeable allowance system could not only fail to achieve the objectives of the global warming Convention, but could make the problem worse. If entitlements were transferred without ensuring that the appropriate compensating reductions were achieved, total emissions could rise, thereby violating one of the fundamental premises of the programme" (see also Gardner 2000, p. 162).

This is not to say that tradeable quotas are inappropriate for reducing global greenhouse-gas emissions, only that the case for emissions trading has yet to be made. What is required is a comparative assessment of the *total* costs – the expected value of the sum of compliance/abatement costs, monitoring costs, enforcement costs, and residual pollution costs – of a tradeable quota scheme and alternative instruments. Until such a total-cost assessment is made, the case for

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[12] This may be the case for economically advanced, as well as developing, countries. Fraschini and Cassone (1994, p. 102) conclude, for example, that the absence of economic instruments from Italy's water-pollution control regime are due the "quite backward" state of emissions monitoring and enforcement technologies in that country.

[13] This analysis is not to be taken as an endorsement of the need for any particular reduction in global greenhouse-gas emissions. We only assume the goal of reducing such emissions for purposes of the analysis.

tradeable quotas remains underdetermined.

4. Concluding Remarks

It is clear that there is no universal, first-best approach to achieving environmental protection goals in this second-best world. The determination of the *best* approach is situational – dependent on institutional, technological, and other factors. As modeled in this paper, the best approach is the one that achieves the environmental protection goal at the lowest total cost, where "total cost" is defined as the expected value of the sum of compliance, administrative, and residual pollution costs. Focusing on compliance-cost minimization, without regard to administrative and residual pollution costs, is insufficient and indefensible in policy making.

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