

1-1-1999

When is Command-and-Control Efficient? Institutions, Technology and the Comparative Efficiency of Alternative Regulatory Regimes for Environmental Protection

Peter Z. Grossman

Butler University, pgrossma@butler.edu

Daniel H. Cole

Follow this and additional works at: http://digitalcommons.butler.edu/cob_papers

 Part of the [Management Sciences and Quantitative Methods Commons](#)

Recommended Citation

“When is Command-and-Control Efficient? Institutions, Technology and the Comparative Efficiency of Alternative Regulatory Regimes for Environmental Protection,” (with Daniel H. Cole), *Wisconsin Law Review*, 1999, November 1999. Reprinted in *Land Use and Environmental Law Review*, 31, 2001.

This Article is brought to you for free and open access by the College of Business at Digital Commons @ Butler University. It has been accepted for inclusion in Scholarship and Professional Work - Business by an authorized administrator of Digital Commons @ Butler University. For more information, please contact fgaede@butler.edu.

When is Command-and-Control Efficient? Institutions, Technology and the Comparative Efficiency of Alternative Regulatory Regimes for Environmental Protection.

The nominal efficiency of a regulatory regime is determined by comparing its social costs and benefits; the regime is nominally efficient if it produces benefits in excess of its costs. Thus, a regulatory regime can be at once nominally efficient and relatively inefficient. A regulatory regime that is nominally efficient in the early days of pollution-control efforts, when increments of environmental quality are relatively cheap, may (but will not necessarily) grow less efficient over time - producing less return on each dollar invested - as increments of environmental quality grow increasingly expensive. A regulatory regime that is more efficient in one institutional and technological setting may be less efficient (or inefficient) in another. In reality, however, this outcome will occur only under certain conditions; specifically, when the regulatory regime as a whole is more efficient. The discussion begins, for the sake of comparison, with a brief review of the "conventional" story of the Clean Air Act's regulatory regime. In addition, in 1987 the EPA wrapped up a small-scale and temporary but highly successful experiment in tradable rights to lead-content in gasoline. Like other institutions in society, those of environmental protection (including the regulatory regime itself) tend to evolve slowly, incrementally, and inconsistently. In large measure, the choice of regulatory regime depends on the goals and concerns of policy-makers.

Daniel H. Cole & Peter Z. Grossman

I. Introduction

It has become an article of faith among economists, legal scholars, and policy makers that economic forms of regulation such as effluent taxes and emissions trading are inevitably more efficient than traditional command-and-control regimes for environmental protection. Some suggest that command-and-control regimes are not only less efficient but inherently inefficient, implying that they naturally produce more social costs than benefits.ⁿ¹ A few even go so far as to equate command-and-control with "Soviet-style" regulation and "socialist central planning," implying that it is both endemically inefficient and democratically illegitimate.ⁿ²

[*888] This Article takes issue with the general portrayal of command-and-control environmental regulations in the economic and legal literature. The prevailing view that command-and-control is inevitably inefficient - or less efficient than alternative "economic instruments"ⁿ³ such as effluent taxes and marketable pollution permits - is inaccurate both as a matter of economic theory and experience. This Article argues that command-and-control environmental regulations can be (and have been) nominally efficient, producing social benefits in excess of their costs; indeed, they even can be (and have been) more efficient than alternative "economic" approaches to regulation.

Standard economic accounts of command-and-control environmental regulations are insensitive to the historical, technological, and institutional contexts that can determine the comparative efficiency of alternative regulatory regimes. A regime that is nominally or relatively efficient in a given set of historical, technological, and institutional contexts may be nominally or relatively inefficient in another context. As Hodgson puts it, "What is 'fit' is always relative to an

environmental situation." ⁿ⁴ When analyzed with sensitivity to historical, technological, and institutional contexts, command-and-control regulations are not, contrary to the prevailing wisdom, invariably inefficient or necessarily less efficient than "economic" mechanisms for environmental protection. Indeed, in some cases, given the marginal costs of pollution control, technological constraints, and existing institutions, command-and-control [*889] can be the most efficient means of achieving a society's environmental protection goals.

Section II of this Article reviews the empirical literature upon which others have relied to condemn command-and-control regulation. The studies do not, as it happens, lead inexorably to the conclusion that command-and-control is inevitably inefficient or even less efficient than alternative "economic" approaches to regulation. Section III then sketches a dynamic model of environmental protection that accounts for the changing marginal costs of environmental protection over time, technological constraints, and institutions and institutional change. The model is further elaborated in Section IV through a series of five stylized cases, which demonstrate how alternative approaches to regulation are more or less efficient depending on institutional and technological factors that affect overall regulatory costs. Section V then adds empirical support by reviewing the history of the United States Clean Air Act. This Section demonstrates how efficiencies can shift in response to institutional and technological evolution. In the early years of federal air pollution control, congressional reliance on command-and control regulations was nominally efficient and probably also relatively efficient, but recent technological and institutional innovations made market-based alternatives feasible, and in some cases efficiency-enhancing.

II. The Premature Burial of Command-and-Control: What the "Empirical" Studies Prove and Do Not Prove

"Empirical" studies allegedly confirm the inherent inferiority of command-and-control regulations. Tietenberg, for example, has summarized ten studies that he claims demonstrate vast cost differentials between command-and-control regulations and least-cost alternatives. ⁿ⁵ In fact, these studies prove rather less than he claims. In the first place, only one is actually "empirical"; ⁿ⁶ the others are simulations or predictive studies based on models. ⁿ⁷ The only truly empirical study, an examination [*890] of control policies for meeting air quality standards in the Lower Delaware Valley, does not conclude that market-based approaches are inevitably more efficient than command-and-control. In fact, the "most striking" finding of the study is that

although the ambient quality permit policy [a market-based approach] was generally observed to be the most efficient of the source control policies analyzed and the uniform percentage emission reduction policy [a command-and-control approach] was most often the least efficient of those analyzed, there were enough exceptions to these findings to be cautious about making generalizations. Moreover, the two source control policies that have attracted and continue to attract the most attention among environmental economists and policy analysts - the uniform emissions charge and emission permit policies - were surprisingly erratic from an efficiency perspective. The uniform emission charge policy in one case, for example, was the most efficient

of the source control policies analyzed. In another case, it was the least efficient of those analyzed, even more costly than the uniform percentage emission reduction policy.ⁿ⁸

Moreover, this and several of the other studies focus exclusively on compliance costs, ignoring implementation and monitoring costs.ⁿ⁹

Among the studies that do consider administrative costs, the findings are mixed. For example, although Palmer et al. find that "economic incentives impose lower costs on the economy as a whole and offer far greater flexibility in both the timing and extent of emissions reduction," they conclude that "no policy ranks first among all the dimensions of policy comparison." Consequently, they do not "recommend a particular choice among the policy strategies."ⁿ¹⁰ Roach et al. conclude that although certain market-based approaches may, in theory, be more efficient, one must account for the legal and political (i.e., institutional) context in which they would operate.ⁿ¹¹ Hahn and Noll go a step further, concluding that market-based approaches are not invariably more efficient than command-and-control for institutional (mainly political) [*891] reasons, as well as for reasons pertaining to the nature of specific pollution problems.ⁿ¹² Similarly, Seskin et al. note:

It would be premature to conclude that the less costly [market-based] strategies ... would necessarily be superior in practice to more traditional regulatory approaches. This follows from the fact that the policy instruments needed to implement the less costly strategies may be unavailable because of legal or political constraints, or may be so costly to administer as to offset the potential savings in emissions control costs.ⁿ¹³

In other words, the "less costly" regulatory strategies may not be less costly after all. Perhaps most interestingly of all, Maloney and Yandle suggest that "when information costs are considered, one might argue that the development of clean air regulation since 1970 has actually been the best possible approach" because

there are a number of practical problems associated with both plant standards and regionally marketable permits. The monitoring question is most dominant. The technological basis of the uniform percentage source standards has been itself the monitoring device. If the approved technology was in place, and its working order documented, emission control was being accomplished. With transferability, more direct measurement of emissions might be required.ⁿ¹⁴

These various empirical studies, far from demonstrating the inevitable superiority of market-

based approaches to pollution control, as Tietenberg has suggested, ⁿ¹⁵ show that conceivable market-based approaches would in many cases perform more efficiently than command-and-control regulations, assuming certain institutional and economic circumstances. Meanwhile, Tietenberg neglects empirical studies that demonstrate how command-and-control regulations, in some cases, have been more effective than effluent taxes or prices in conserving resources and reducing pollution. Greene, for example, found that federal Corporate Average Fuel Economy (CAFE) standards are "twice as important an influence as gasoline prices" in creating incentives [*892] for automakers to develop more fuel efficient cars. ⁿ¹⁶ Most importantly, and contrary to the prevailing view, ⁿ¹⁷ the existing "empirical" studies do not demonstrate either that command-and-control regulations are inherently inefficient or that they are invariably less efficient than market-based alternatives.

III. An Alternative Approach to Modeling the Comparative Efficiency of Alternative Regulatory Regimes

The prevailing view of alternative regulatory regimes is oversimplified in at least three ways: (1) it overemphasizes the differences between command-and-control regulations and "economic" instruments for environmental protection; (2) it conflates nominal and relative economic efficiency in comparing alternative regulatory regimes; and (3) it tends to be ahistorical and acontextual, ignoring changes over time in marginal costs, technological capabilities, and regulatory institutions.

As Davies and Mazurek have noted, the distinction between command-and-control regulations and economic instruments, such as marketable emissions permits, is "not as stark as it appears... Most of the market approaches that have been used in the United States operate within the standard command-and-control framework." ⁿ¹⁸ For example, the sulfur dioxide trading regime under the 1990 Clean Air Act amendments is simply an administrative command without attendant controls (i.e., an emissions quota without a specified means for meeting the quota). There are some incentive programs that are not tied to regulatory regimes, such as gasoline taxes, but as Davies and Mazurek note, such pure market-based regimes are "difficult to formulate and often are stoutly resisted by the entities to which they would apply." ⁿ¹⁹ In other words, the costs of instituting pure market-based incentives for [*893] pollution control (without any elements of administrative commands or controls) can be prohibitively high, despite their theoretical efficiency advantages.

In addition, the standard account of market-based environmental protection versus command-and-control conflates nominal and relative efficiency. The nominal efficiency of a regulatory regime is determined by comparing its social costs and benefits; the regime is nominally efficient if it produces benefits in excess of its costs. And it remains nominally efficient even if it turns out to be less efficient than (or relatively inefficient compared to) some real or imagined alternative regulatory regime. Thus, a regulatory regime can be at once nominally efficient and relatively inefficient. ⁿ²⁰ This may seem a trivial point but, as shall become apparent, the conflation of nominal and relative efficiency has often misled scholars, policy analysts, and politicians into condemning all command-and-control regulations as uneconomic and counterproductive, though some command-and-control regulations have clearly produced substantial net social benefits.

The prevailing view of comparative efficiency also tends to be ahistorical and acontextual, treating market-based approaches as if they were always more efficient, and therefore more appropriate, than command-and-control regulations.ⁿ²¹ But this is not the case. This Article will demonstrate that institutional settings exist in which command-and-control regulations tend to be more efficient (and sometimes more effective) than market-based regulations. Thus, the relative efficiency (and efficacy) of alternative regulatory regimes cannot be determined in isolation from the institutional context in which they operate.ⁿ²²

[*894] Moreover, the comparative efficiencies of alternative regulatory regimes change over time, as the demand for pollution control grows and the marginal costs of pollution control change.ⁿ²³ A regulatory regime that is nominally efficient in the early days of pollution-control efforts, when increments of environmental quality are relatively cheap, may (but will not necessarily) grow less efficient over time - producing less return on each dollar invested - as increments of environmental quality grow increasingly expensive.ⁿ²⁴ However, as marginal costs rise under one regulatory regime, they may spur the development of alternative, less costly regulatory policies as well as new technologies that make further increments of environmental quality efficiently attainable. Such innovations may not be adopted wholesale or implemented overnight because of the high transaction costs commonly associated with institutional, technological, and policy changes.ⁿ²⁵ But at some point the benefits of a regime change may come to outweigh the transaction costs. If and when they do, regulatory policy will tend to evolve, if only incrementally and rarely uniformly,ⁿ²⁶ in the direction of increased efficiency, making affordable additional increments of environmental quality that were unaffordable under the preceding, and now relatively less efficient, regulatory regime.

This Section has just sketched a dynamic model of environmental protection that takes seriously both institutional and historical contexts. Part IV will elaborate this model through a series of five hypothetical cases, designed to illustrate how institutional and technological variables can determine the comparative efficiency of alternative regulatory regimes. A regulatory regime that is more efficient in one institutional and technological setting may be less efficient (or inefficient) in another. Finally, Part V supports the model with an empirical study of the history of federal air pollution control law in the United States.

[*895]

IV. Taking Institutional and Technological Context Seriously: Hypothetical Case Studies in the Comparative Efficiency of Alternative Regulatory Regimes

When economists, legal scholars, and policy analysts compare alternative regulatory regimes, they typically present a dichotomy: presumptively inefficient command-and-control regulations versus presumptively more efficient "economic" instruments, such as marketable permits. This dichotomy is accurate often enough; in many circumstances market or quasi-market mechanisms operate more efficiently than command-and-control regulations. But the dichotomy is not wholly and invariably accurate. There are institutional settings in which markets are not only less efficient than command-and-control regulations but are in fact completely ineffective in reducing pollution. In the real world, the relative efficiency with which a particular regulatory regime maximizes a social welfare function depends on institutional and technological circumstances.

As Weitzman has noted, "there may be important practical reasons for favouring [one among alternative] planning instruments. These reasons might involve ideological, political, legal, social, historical, administrative, motivational, informational, monitoring, enforcing, or other considerations." ⁿ²⁷

To illustrate the role of technological and institutional factors, the following subsections examine five hypothetical "cases" in which the efficiency of a pollution-permit trading regime is compared with that of a command-and-control regime. It is worth noting that these two regimes are not so distinct as some scholars have suggested. In both instances, an authority sets a quota that is backed by statutory sanctions. The only real distinction is in the means chosen for meeting the quota. With command-and-control, the authorities specify the means (usually technological) for attaining the emission-reduction goal; with emissions trading, by contrast, the authorities allow the market (comprised of regulated industries) to determine how to achieve the emission-reduction goal. In a real sense, a pollution permit trading regime is a system of command-without-control.

A. Case 1 (The Ideal Case): Perfect Property Rights, Perfect Information, and Perfect Markets

To begin, consider the idealized setting of an efficiently operating market economy (with attendant institutions) in which property rights are perfectly specified. All environmental goods (including, for example, the [*896] atmosphere) have been parcelized and allotted to individual owners who possess and can enforce through the legal system typical property rights to use, exclude, and trade. In this ideal world benefit and cost functions are fully known; a social welfare function is completely specified; the authorities always maximize the net dollar value of social welfare; information costs for all people in society are low, so that the level of pollution and the distribution of costs and benefits are both always known; and bargaining (and other transactions) are essentially costless. This is the world of the Coase theorem, and in it social costs and benefits equal private costs and benefits. ⁿ²⁸

The level of pollution abatement in this ideal world is the point at which marginal benefits (MB) equal marginal costs (MC), as shown in Figure 1. Optimal levels of abatement will be y^* at a marginal cost p^* . Because the optimal level of pollution control is automatically attained by virtue of the assumptions of perfect markets, perfect information, and perfect specification of property rights, government intervention to protect the environment cannot enhance efficiency. With property rights completely specified, there should be no significant and uncompensated-for (i.e., no inefficient) externalities, ⁿ²⁹ and hence no market failures requiring correction. ⁿ³⁰ Any government-mandated pollution reductions would produce more costs than benefits for society.

Needless to say, this ideal world does not exist. In the real world, property rights are always imperfectly specified; social welfare functions, which presumably underlie government action, are imperfectly delineated; information is incomplete and asymmetrical; and transaction costs of various kinds are always positive and may be quite high. ⁿ³¹ Thus, the market does not automatically achieve the optimal level of pollution control. And government intervention for environmental protection may, but does not necessarily, enhance efficiency. ⁿ³²

[*897]

Figure 1: This figure presents the standard depiction of efficiency in pollution abatement. At y^* the optimal level of abatement is achieved by definition.

[SEE FIGURE IN ORIGINAL]

B. Common Assumptions of Cases 2-5

Real-world environmental problems and regulatory solutions require substantial deviation from the assumptions of the ideal case. Changing the assumptions leads to different assessments of the comparative efficiency of alternative regulatory regimes. The four cases that follow are designed to illustrate that a single regulatory approach may be relatively efficient in some institutional and technological contexts but relatively (and even nominally) inefficient in others.

Each of the four cases relies on the following five assumptions:

- (1) the political-economic system is one of incomplete property rights and imperfect information;
- (2) complete benefit and cost functions are not known (and cannot be known) ex ante;
- (3) the government endeavors to institute efficient regulation, and so sets exogenously a level of pollution abatement (y), which is expected to improve social welfare;
- [*898] (4) the government assumes that each increment of abatement (y) provides some social benefit; and
- (5) all polluters are not identical in their costs of control.

The government faces a benefit function in which benefits (B) increase in the quantity of abatement; that is, all abatement adds some positive benefits. The level of benefits, however, is subject to uncertainty because an exact measure of benefits can only be imperfectly estimated before any regulatory regime is implemented.ⁿ³³ Put another way, the government explicitly or implicitly estimates a range of possible levels of benefits from any given quantity of abatement, but expected benefits will vary around a mean value to a greater or lesser extent depending on the degree of uncertainty.ⁿ³⁴ For example, benefits typically include the discounted value of long-run health benefits, but this value must be sensitive to estimates not only of discount rates and projected health care costs but also to an estimate of the health care costs that would have been incurred in the absence of abatement, since this would be a cost foregone through abatement and must be considered a component of net benefits. It is assumed, then, that the function can be approximated within a range, although this range may be quite large depending on the information available to the authorities. If returns are increasing, marginal benefits may likewise be increasing over a certain range, but it is assumed that at a given quantity of abatement marginal benefits are positive but falling in y .ⁿ³⁵

Costs are defined by a similar function. Cost (C) will depend on the amount of abatement (y) and the level of uncertainty about future costs. However, costs are also assumed to be a function of institutional variables - notably the cost of administration, compliance monitoring, and enforcement of any regime given a particular political-economic system and technological capability. Institutional variables may have one or two effects on the cost function. First, they may act as a shift parameter; that is, given known costs of abatement technology and the institutional capability to implement and enforce a particular regime, the cost range will shift up or down. In addition, institutional variables may either decrease or increase uncertainty. Put another way, institutional factors will be functionally related to both overall costs and uncertainty. [*899] Thus, where a regime requires contract enforcement, but enforcement institutions are weak and operate inconsistently, there may be greater uncertainty and greater expected variance concerning the ultimate cost of achieving the desired level of abatement.

The marginal cost curve, though highly dependent on uncertainty and institutional factors, will nonetheless be assumed to be rising in y. ⁿ³⁶ In a world of perfect information and perfect markets, the marginal cost curve would be unaffected by institutional costs. However, here it is assumed more realistically that institutions do entail costs. Indeed, in some cases institutional costs approach infinity.

Institutional variables are included here to imply that in many cases, regulators may select a regulatory regime that is "second best" from the standpoint of theory but more efficient in the institutional and technological context. Meanwhile, the alternative that is "first best" in theory may not be feasible in the institutional and technological context at finite cost, or at a cost lower than the "second best" alternative. In other words, the "second best" regime may be the "first best" solution, given practical considerations or local conditions.

The authorities presumably seek to attain the optimal level of abatement. To do so, they select a quota level of abatement (y). Since the benefit and cost functions are uncertain and may reflect the institutional setting as well as uncertain information, regulators face the problem illustrated in Figure 2. The marginal benefit is estimated to fall between MB1 and MB2; marginal costs between MC1 and MC2.

Consider a scenario in which the authorities decide to use an estimate of benefits at the mean of the range. At the same time, rather than choose the mean of the cost range, they choose the highest extreme of marginal costs for ex ante calculation (perhaps in order to minimize the political costs of instituting a mistaken policy). An equilibrium price and quantity will thus be reached at point D. However, if marginal benefits are higher (say, on MB1), y will have been set too low, and the area DBA will represent a deadweight loss. Similarly, if the benefits schedule is closer to MB2, y will clearly have been set too high and some social loss (the area DFC) will result. The greatest social loss occurs if benefits are at the highest and costs at the lowest of their respective ranges (at G). Here the area BHG represents a social loss. In any case, if these curves are imagined as an infinite set of possible results given various regulatory regimes as well as various states of the world, ex ante it is unlikely that the level of abatement chosen by the authority would prove to be optimal, and some ex post inefficiency would result.

Upon setting y , government authorities select from among regulatory regimes $i=1, 2, 3, \dots, j$, which are defined by a set of cost functions C_i .

[*900]

Figure 2: Each point—B, D, H, or C—represents levels of marginal costs and benefits that may be achieved with positive probability at abatement quantity y . They may represent efficient levels if marginal benefits equal marginal costs at those points. However, if $MC_2 > MB_2$ obtains, then attaining y will mean that there is some social loss (represented by the area ECH). Other shaded areas represent social welfare losses, depending again on various combinations of marginal costs and benefits.

[SEE FIGURE IN ORIGINAL]

Any of these regimes may achieve y (although not necessarily at finite cost), but regulators pick the regime with the lowest expected total cost and greatest predicted efficiency. As between any two regimes, however, one may be relatively more efficient in a particular institutional and technological context than the other.

Figure 3 illustrates this. In this figure, marginal benefits are assumed to be independent of the regime that is chosen. Marginal costs are estimated to fall either in the range MC_1 - MC_2 or mc_1 - mc_2 . For example, the MC_1 - MC_2 range may be expected marginal cost of a market-based regime; the mc_1 - mc_2 the expected marginal cost of a command-and-control regime. In this case, the command-and-control regime has a marginal cost with a lower mean and smaller variance.

Consequently, it would be expected to be the less costly regime. It is important to note that regulators' expectations could turn out to be mistaken. Consider the case where ex post costs of the market-based regime are closer to MC_2 and the command-and-control costs closer to mc_1 . In that case, the market-based approach would be more efficient. But that case is relatively unlikely to occur. Given its greater expected ex ante certainty and probable efficiency gains, command-and-control is likely to be the more efficient choice. It is important to recognize that whichever equilibrium (in Figure 3) is realized ex post, enacting the

[*901]

Figure 3: The ranges MC_1 - MC_2 and mc_1 - mc_2 represent, respectively, the costs of an economic instrument (an effluent tax or tradable-permit program) and a technology-based command-and-control program at a given point in time. Both entail considerable ex ante uncertainty, but the command-and-control program (mc_1 - mc_2) has a lower expected cost on average and therefore the largest expected net benefits, given the benefit range MB_1 - MB_2 .

[SEE FIGURE IN ORIGINAL]

regulatory program in the first place is efficiency-enhancing. Choosing y and actually achieving it, even in the worst cases depicted in Figures 2 and 3, is Kaldor-Hicks superior to a world in which no regulation takes place; that is, the regulatory regime yields net social benefits in moving from the status quo ante.ⁿ³⁷

It is possible, of course, to imagine a case, depicted in Figure 4, in which this would not be true. Figure 4 represents the exact same problem as Figure 2, but the marginal cost range, for institutional reasons, is shifted slightly upward and to the left, and the overall range is expanded because of greater variance. If in fact MC1 occurs, the cost curve will be so steep that to reach y total costs must exceed total benefits. (Net costs, represented by the area CFH, exceed net benefits, represented by the area IJC.) Point D, though representing something of a mean value for both benefits and costs, is not attainable if costs exceed the mean. Indeed, a cautious authority, unsure of reaching a level of y beyond C where benefits exceed costs, might choose instead to implement a lower y . Alternatively, the authority might choose a different regulatory regime that offers a greater level of certainty in attaining y , even if that alternative regime is in theory (and in the absence of uncertainty) less efficient. In other words, the range of uncertainty of the costs of attaining y can skew the relative efficiency of alternative regulatory regimes.

[*902]

Figure 4: This figure shows how total costs may exceed total benefits. If marginal costs are MC1 and marginal benefits are MB2, then the total costs will be greater than the total benefits at y . Total costs and benefits would be represented by the area under each curve. In this case, total costs are the area under JF; total benefits are the area under IH. The net total loss is represented by the area of the triangle CFH, minus the area of the triangle IJC. Note that in this scenario, the efficient level is at C.

[SEE FIGURE IN ORIGINAL]

For the sake of both simplicity and realism, institutional variables and constraints are assumed to be independent; that is, these cases do not assume that enforcement costs will be high just because monitoring costs are high. It is, of course, possible in the real world for enforcement costs to be high because monitoring costs are high, but it is not invariably the case.

These cases also assume (again, for the sake of simplicity) that there are only two alternative regimes for pollution control. In the first (Regime 1), the government imposes command-and-control pollution abatement, e.g., the mandatory installation of abatement technology by all regulated polluters regardless of their differential compliance costs. In the second (Regime 2), the government issues a limited number of pollution allowances, which regulated polluters can freely trade to minimize compliance costs.

Most analysts assume, all other things being equal, that the total costs of pollution control will be lower under Regime 2; by directing the bulk of the pollution-reduction burden to low-cost abaters, a marketable permit system should provide (at least) as much pollution control as Regime 1 at lower cost. In reality, however, this outcome will occur only under certain

conditions; specifically, when the regulatory regime as a [*903] whole is more efficient. For example, permit trading requires a more elaborate (hence, more costly) technological and institutional structure for monitoring compliance than do technology-based command-and-control regulations.ⁿ³⁸ This can affect the overall efficiency of Regime 2, even to the point of reversing its theoretical economic superiority over Regime 1. In addition, depending on the institutional and technological context, one regime may be far more costly to establish than another, shifting total cost curves. This may be especially true for tradable permit schemes where market institutions are weak because, for example, budget constraints are soft. But again, for simplicity's sake, these cases assume that fixed costs for both regimes are identical.

Cases 2 through 5 will now compare the hypothetical performance of the two regimes to illustrate how the relative (and sometimes nominal) efficiency of each depends in large measure on the institutional and technological context.

C. Case 2: High Abatement Costs; Low Monitoring and Enforcement Costs

High abatement costs would lead the government to prefer Regime 2 over Regime 1 because the bulk of abatement under Regime 2 will come from relatively low-cost abaters, whereas under Regime 1, all regulated entities must reduce emissions by the same amount, regardless of their differential costs of abatement. Meanwhile, because monitoring and enforcement costs are low in this setting, they will have less impact on the overall cost structure, providing no reason to prefer one regime over the other. Consequently, the total costs of Regime 2 are likely to be lower than the total costs of Regime 1 in this case. This is not to say that Regime 1 is inefficient - that would depend on whether it is economically superior to no regulation at all - but Regime 1 is almost certain to be less efficient than Regime 2.

This case reflects the conventional wisdom that marketable permit systems are more efficient than command-and-control regulations because they are less costly. But this depends on the assumption that monitoring and enforcement costs are not significantly higher for one regime than for another. In the real world, this assumption does not always hold, and Case 3 illustrates how the estimates of relative efficiency change when it does not.

[*904]

D. Case 3: Low Abatement Costs; High Monitoring Costs

In the case of low abatement costs and high monitoring costs, increments of environmental quality are relatively inexpensive; that is, under either Regime 1 or Regime 2, the technology exists that will provide additional units of pollution abatement at low marginal cost. At the same time, emission monitoring capabilities are deficient; the authorities can measure ambient concentrations of pollutants, but perhaps no low-cost technology exists to permit the precise measurement of emissions at individual sources. If the government selects a regulatory regime that requires precise measurement of emissions at individual sources, monitoring costs will be higher and ex ante uncertainty about ultimate costs will be higher; the marginal cost range will shift upward; and the expected variance will be greater.

In this case, Regime 1 may entail lower total costs than Regime 2. If the government simply orders all potential polluters to install available pollution-reduction technology (such as scrubbers), it can be confident of achieving some amount of emissions reduction, even if it cannot precisely measure how much. The installation and operation of the technology itself constitutes the attainment of the desired level of abatement (y).ⁿ³⁹

By contrast, under the technological constraints assumed in this case, Regime 2 may not provide an effective or efficient solution. Consider a case in which the government wishes to reduce emissions by fifty percent. To accomplish this under Regime 2, the authorities must (1) determine current emissions levels, (2) divide that amount in half, and (3) allocate the remainder among the regulated polluters. Subsequently, the authorities would have to (4) continuously monitor their emissions to ensure that they did not exceed their quotas. But lacking the ability to monitor emissions at individual sources, the government would be unable to complete steps (1) or (4), which would prevent a transferable pollution "rights" program from ever getting off the ground. Polluters would have scarce incentive to either abate emissions or trade allowances if their emissions levels could not be measured.ⁿ⁴⁰

In this instance, it seems clear that a command-and-control approach, because it does not depend on individual point-source [*905] monitoring, would be relatively effective and efficient compared to a transferable pollution "rights" program. This does not mean that Regime 1 would be optimally efficient or very effective, but under the circumstances Regime 1 - the "second best" - would be a better alternative.ⁿ⁴¹ This hypothetical case fairly represents the circumstances that confronted Congress in 1970, when it enacted the Clean Air Act, which is examined in Part V. This case also reflects continuing circumstances in many countries with primitive monitoring and enforcement technology. Fraschini and Cassone, for example, suggest that the "quite backward" state of emissions monitoring and enforcement technology in Italy "explains why economic instruments ... are virtually absent" from Italian water pollution control policy.ⁿ⁴²

This case and the previous one are both static. While a government regulator will need to use cost estimates based on what is known at the time the regulatory regime is selected and implemented, cost curves will likely change over time. Both technological and administrative costs may shift as a result of changes in productivity or factor prices. Of course, such changes may shift the curves up or down, and may increase or decrease the variance. However, progress along learning curves as well as technological change will more than likely shift and narrow the marginal cost curves, as shown in Figure 5 (in shifting from time t to time $t+1$). If this shift in the range of marginal costs represents a fall in monitoring costs (thanks to technological or institutional innovations), Case 3 could evolve into Case 2.ⁿ⁴³ That is, it might become cost-effective and Kaldor-Hicks improving to change from a regulatory regime that minimizes monitoring costs (Regime 1) to one that minimizes abatement costs (Regime 2).

It is also likely that the range of benefits will narrow as more information on actual benefits is gathered over time; the superior information can then be more reliably extrapolated. Total benefits may also grow as population rises or as evidence reveals unanticipated gains. Moreover, as these benefits and costs become less uncertain, regulators can approach the Kaldor-Hicks optimal outcome (y^*) by raising or lowering abatement quotas.

[*906]

Figure 5: As monitoring technology improves and costs become more certain over time (from time t to $t+1$), the range of marginal costs becomes both narrower and lower, making additional abatement efficiently attainable.

[SEE FIGURE IN ORIGINAL]

E. Case 4: A Non-Market Economy with Endemic Soft Budget Constraints but Hard Law Constraints

The last two cases assumed an important institutional characteristic: that the regulatory regime was operating within an efficient market-based economic system. But in many parts of the world, even after the fall of communism in Europe, economic activity is either not market-oriented at all or occurs within inefficient markets.

The present case assumes a non-market (that is, an administered or command) economic system, in which the State is the dominant player, owning or controlling a large share of the means of production. This case further assumes, following Kornai, that state enterprises in this command economy operate under soft budget constraints, so that their survival is determined not by profits and losses in the market but by political criteria - quantity of output, most commonly - as set by central-government administrators.ⁿ⁴⁴ So long as enterprises meet or exceed planned production targets, they will be maximally rewarded with increased budget allocations from the central government. However, this case assumes that these state enterprises still face hard law constraints; that is, the state can and will enforce regulatory requirements against them.ⁿ⁴⁵

[*907] In this case, Regime 2 cannot possibly work. First, there might not be any market within which transferable pollution "rights" would meaningfully be priced.ⁿ⁴⁶ The MC range would be shifted drastically upward to the left (as illustrated in Figure 6). Moreover, regardless of the price of pollution "rights," state-owned enterprises operating under soft budget constraints are unlikely to participate in pollution "rights" trading because participation would be unlikely to enhance their profitability. Again, their economic survival does not depend on profits or losses but on their ability to maximize output, regardless of efficiency. Enterprises operating under these rules are unlikely to engage in activities such as pollution control that might reduce total output, even if doing so would enhance efficiency. Meanwhile, any financial penalties enterprises might incur for not reducing pollution (assuming the government can monitor compliance at reasonable cost) would have little impact on profitability because of the endemic soft budget constraints. So long as enterprises meet their annual plan production targets, they will be compensated for any environmental penalties with increased budget expenditures.

The nature of the incentive structure in the command economy is such that polluters have every reason not to expend resources on pollution control when doing so might jeopardize their abilities to meet state-mandated production goals. As Figure 6 shows, for a transferable pollution "rights" program, given the shift in costs, the equilibrium level of y is far below $\langle \text{cir } y \rangle$, which could not in fact be achieved at any finite cost. In sum, market-based approaches to pollution control cannot be effective in either a non-market economy or a market economy characterized

by soft budget constraints (which will probably obtain in some mixed economies with dominant state-owned industries).ⁿ⁴⁷ And because a pollution "rights" trading regime cannot possibly achieve the desired result of maximizing social welfare where $B > C$, such a regime is not only less efficient compared with command-and-control but nominally inefficient.

In this case, Regime 1 becomes the only feasible alternative. Because law constraints are hard, the government will enforce its command-and-control regulations against polluters who would otherwise costlessly ignore fees, fines, or other "market-based" incentives to reduce pollution under Regime 2. Although a technology-based command-and-

[*908]

Figure 6: In this case, though y is mandated by regulators it cannot be attained at finite cost. Technological and/or institutional change is required to reach that level. More realistic regulators should set y between points EB and ED.

[SEE FIGURE IN ORIGINAL]

control regulation may be less efficient than some unrealizable ideal, it is clearly more efficient than any alternative market-based solution given the institutional constraints of this case. Indeed, this case presents in sharp relief the problem of institutional context: A certain regulatory regime that is effective and efficient in one institutional setting may not be effective or efficient in another.

F. Case 5: A Non-Market Economy with Endemic Soft Budget Constraints and Soft Law Constraints

This final case is based on the same assumptions as Case 4 with one vitally important change: In addition to soft budget constraints, the command economy is characterized by soft law constraints, which means that the government is unlikely to enforce its regulations against state enterprises. This case represents the actual state of affairs before the fall of communism in many Soviet bloc countries. For example, in People's Poland, as Cole has shown, environmental laws were fairly sophisticated and standards were strict (in some cases, stricter than comparable American standards).ⁿ⁴⁸ Moreover, Poland's environmental protection regime relied heavily on market mechanisms; specifically, per-unit emission fees and fines. However, under socialism, Poland's environmental protection regime failed because law and budget constraints were both soft; legal regulations were only rarely enforced against state enterprises, which also had no market incentives to conserve [*909] resources or minimize pollution, since they were insensitive to the price signals of environmental fees and fines.

When budget and law constraints are both soft, environmental regulations are ineffective no matter which regulatory approach is selected. Even if all uncertainty is eliminated, y cannot be attained. Neither Regime 1 nor Regime 2 can be effective or efficient. In this case, institutional and/or technological change becomes a necessary prerequisite for effective environmental protection.

G. Limitations of the Analysis

The various cases in this Section only approximate real-world situations. Moreover, many other possible cases (and variations on cases) that might affect the comparative efficiency analysis have been excluded. This Section has focused on just a few variables that seem to be of great importance in just a few simplified cases, and not all possible relations between them are included here. Nevertheless, the five cases explored in this Section should be sufficient to demonstrate the importance of context for determining the comparative efficiency of alternative environmental protection regimes. A regulatory approach that is both nominally and relatively efficient in one setting may be relatively and even nominally inefficient in another. In order to understand properly regulatory regimes and the ways they evolve over time, attention must be paid to the institutional and technological contexts that can greatly influence cost structures and incentives.

V. A Historical Study in the Efficient Evolution of Regulatory Policy: Federal Air Pollution Control in the U.S., 1970-1990

This Section concerns not a stylized case but a real, evolving case: federal air pollution control under the Clean Air Act, 1970-1990. The analysis suggests that, given existing institutional constraints and technological capabilities, both the early reliance on command-and-control regulations and subsequent incremental experimentation with market-based solutions such as transferable pollution "rights" programs have generally been efficient. The discussion begins, for the sake of comparison, with a brief review of the "conventional" story of the Clean Air Act's regulatory regime.

[*910]

A. The Conventional Economic History of the Clean Air Act

The Clean Air Act has been described as "one of the more complicated statutes yet produced by a modern industrial state."ⁿ⁴⁹ The Clean Air Act is characterized by "heavy reliance on administrative expertise and the use of uniform, categorical rules as basic regulatory building blocks" - in other words, command-and-control.ⁿ⁵⁰ "Congress told industry what it could and could not belch from its smokestacks, how clean it would need to make new cars, and the type of pollution control devices it would have to install."ⁿ⁵¹ These command-and-control regulations were viewed as "blunt" and "often wildly inefficient and ... "irrational" instruments for achieving environmental goals.ⁿ⁵²

The main goal of the Clean Air Act of 1970 (and still its main goal today) was the attainment, 100% of the time, of national ambient air quality standards, which are a set of maximum permissible atmospheric concentrations of pollutants over various time periods. Congress ordered the newly created Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQSs) for pervasive air pollutants, such as carbon monoxide, sulfur dioxide, and dust (particulate matter), building in an "adequate margin of safety" to protect the health of even the most sensitive human populations without regard to cost.ⁿ⁵³

In order to attain the economically oblivious NAAQSs, Congress relied on a number of even more dubious (according to the standard neoclassical perspective) tools. First, legislators ordered the EPA to set technology-based emission standards without regard to differential costs of compliance across or within industries. All firms within a given regulated industry or category of industries had to achieve the same pollution-control goal, no matter that it cost one firm \$ 100 million to do so but another only \$ 10 million.ⁿ⁵⁴ Moreover, Congress placed the heaviest emission-reduction burdens on new sources through the imposition of New Source Performance Standards (NSPSs), which created perverse incentives. While Congress was correct to presume that new factories could build in emissions-reduction technologies more cheaply than older factories could retrofit them, the Clean Air Act's more [*911] stringent NSPSs induced firms to extend the life spans of older, dirtier factories to avoid building newer, cleaner, and (because of NSPSs) more expensive plants.ⁿ⁵⁵ The technology-based NSPSs also created disincentives for regulated industries to innovate new pollution control technologies that might become the basis for revised NSPSs.ⁿ⁵⁶

The Clean Air Act's NSPSs were also subject to political manipulation (as Public Choice theoryⁿ⁵⁷ would lead one to expect), which compounded their inefficiency. The most famous example may have been Congress's vacillation on performance standards for new coal-fired power plants. In the 1970 Clean Air Act, Congress required the EPA to set emissions standards for new sources based on the best available technology that was adequately demonstrated.ⁿ⁵⁸ The EPA interpreted this mandate broadly: Congress did not intend the Agency to require specific factories to install specific technologies; rather, the Agency was to set emission standards based on available technologies and possible process changes and materials substitution. On this interpretation, the Agency did not have to set standards that would force all new power plants to install scrubbers on smokestacks; instead, some plants might meet emissions standards simply by substituting less polluting but more expensive low-sulfur coal for more polluting but less expensive high-sulfur coal. Economists certainly approved of this more flexible and, therefore, presumably less costly approach to standard-setting. But it [*912] generated an intense political controversy that pitted low-sulfur coal producers, located predominantly in the West, against high-sulfur coal producers, located primarily in the East. Eastern coal interests won a temporary victory in 1977 as Congress amended the Clean Air Act to, in effect, mandate the use of scrubbers at all power plants, regardless of the type of coal they burned.ⁿ⁵⁹ As long as they had to scrub emissions anyway, many utilities that had been burning less polluting, low-sulfur (western) coal switched to more polluting but less expensive high-sulfur (eastern) coal. The ironic result may have been a net increase in national sulfur emissions. Meanwhile, the cost of pollution control for the utility industry went up because end-of-the-pipe solutions like scrubbers tend to be more expensive than process changes and materials substitution.ⁿ⁶⁰

Besides exacerbating the inherent inefficiencies of the pre-existing NSPS program, the 1977 Amendments also added a new program that economists widely condemned. In 1972, a federal district court ruled that the Clean Air Act required the EPA to prevent deterioration of air quality in regions that had already attained the NAAQS.ⁿ⁶¹ Pursuant to this court order, the Agency promulgated Prevention of Significant Deterioration (PSD) regulations that Congress later codified in its 1977 Clean Air Act Amendments. Apparently, Congress agreed that air quality in pristine regions should not be permitted to deteriorate to the level of the NAAQSs (which, after all, were merely intended as floors of minimally acceptable air quality). But assuming the

NAAQSs were properly set, they already were protecting the health of the most sensitive segments of the population of clean-air regions "with an adequate margin of safety." What legitimate basis was there, then, for curtailing economic [*913] development out of concern over marginal, non-hazardous increases in air pollution?

Public Choice theory offered an alternative explanation for the adoption of the PSD program. According to Pashigian,

PSD policy was developed to attenuate the locational competition between developed and less developed regions and between urban and rural areas. The votes cast in the House on PSD policy [in the 1977 Clean Air Act Amendments] ... show opposition to PSD policy comes from the South, the West, and rural locations, areas with higher growth rates and with general superior air quality. PSD policy is opposed in these areas because it places limits on growth. The strongest supporters of PSD policy are northern urban areas, many of whom have lower air quality and are not directly affected by PSD policy. ⁿ⁶²

Pashigian's analysis neglects the fact that Congress did not originate the PSD program but merely codified with relatively minor changes an existing program, which the EPA promulgated under court order. ⁿ⁶³ But this analysis nevertheless explains why Congress did not hesitate to codify the EPA's PSD program in its 1977 Clean Air Act Amendments. By the mid-1970s, many dirty-air regions were under pressure to reduce emissions, to attain the NAAQS, which constrained their own economic development. Nonattainment areas were rationally fearful of a potential large-scale shift in economic development to pristine-air regions. From the perspective of nonattainment areas, the PSD rules merely leveled the economic playing field. Of course, clean-air regions viewed the situation differently; they saw it as a re-tilting of the field back in favor of the already heavily developed areas of the North and East. From their perspective, why should clear-air regions of the West and South be prevented from developing economically merely because of the development mistakes of the North and East? ⁿ⁶⁴

These are just some of the components of the Clean Air Act that, according to some economists and policy analysts, ⁿ⁶⁵ have imposed great costs on society. Hahn, for example, calculates that command-and-control air pollution regulations have cost Americans \$ 30 billion per [*914] year, as an "invisible tax on users of commodities that are produced by industry." ⁿ⁶⁶ And what has been attained for that price? Orts notes that "command-and-control often fails to achieve the environmental results hoped for." ⁿ⁶⁷ Indeed, many regions of the country still fail to meet the NAAQSs for one or more "criteria" pollutants. And the Clean Air Act's program for controlling "hazardous" (e.g., cancer-causing) air pollutants, at least until 1990, has been almost completely ineffective.

The net social benefits of the nation's air pollution control efforts would have been far higher, critics claim, if, from the beginning, the federal government had adopted less costly and more

flexible approaches to regulation than command-and-control. According to some estimates, least-cost approaches would have reduced by a factor of four the total cost of air pollution control.ⁿ⁶⁸

B. An Alternative History: The Clean Air Act's Efficient Evolution

There is much that is true in the conventional story of federal air pollution control. But it cannot be the whole story, because despite all of its alleged inefficiencies, the Clean Air Act has managed to produce sizeable net benefits to society throughout its history.ⁿ⁶⁹ The conventional story is, in fact, substantially misleading because it leaves out many important institutional and technological facts that have affected the relative efficiency of real-world policy choices. Doubtless air pollution goals could have been accomplished at less cost. But the Clean Air Act has been generally efficient, whether in spite or because of its heavy reliance on command-and-control regulations. The conventional history of federal air pollution control efforts ignores three important variables, any one of which can determine the efficacy and efficiency of pollution control efforts: (1) institutional knowledge and learning; (2) technological constraints and innovations; and (3) the changing costs and benefits of pollution control over time. Once these factors are introduced into the analysis, it becomes apparent that federal air pollution control efforts, including the early heavy reliance on command-and-control, have generally been nominally, if not optimally, efficient.

At the outset, it is important to recognize that Congress did not enact the 1970 Clean Air Act *sui generis*. Although it "marked a major change [*915] [from earlier federal air pollution legislation] in priorities, emphasis, and approach,"ⁿ⁷⁰ the 1970 Clean Air Act was founded on regulatory institutions established in earlier enactments, including the 1963 Clean Air Act, the 1965 Motor Vehicle Air Pollution Control Act, and the 1967 Air Quality Act. It is not insignificant that Congress itself labeled the 1970 law "Amendments." Consistent with the theory of "path dependence" - according to which institutional change tends to be incremental and based on pre-existing models, rather than large-scale and path-breakingⁿ⁷¹ - several of the foundations of the 1970 law came from those earlier enactments: Air Quality Control Regions as the jurisdictions of regulation; Ambient Air Quality Standards as the primary targets of air pollution control (though the 1970 Act switched the locus of standard-setting from the states to the federal government); and reliance on health-based and technology-based command-and-control solutions.ⁿ⁷²

A review of the 1970 Clean Air Act's legislative history confirms that Congress intended to improve and build upon pre-existing models, rather than elaborate an entirely novel approach to regulation. Congress was primarily concerned with the need to improve air quality rapidly and with deficiencies in existing monitoring capabilities; Congress did not even consider effluent taxes or tradable emissions permits, although economists and environmental policy analysts were already advocating their use.ⁿ⁷³ In more than 1500 pages of legislative history accompanying the Act, there is but a single reference to effluent taxes as a potential complement to or substitute for emissions standards. During a May 27, 1970 hearing of the Senate Subcommittee on Air and Water Pollution of the Committee of Public Works, Dr. John T. Middleton, Commissioner of the National Air Pollution Control Administration (NAPCA), was asked about the feasibility of effluent taxes for pollution control. He answered that his Agency was looking into the question, and that was the end of it.ⁿ⁷⁴ This lack of attention to economic instruments for air pollution

[*916] control may suggest (on a Public Choice view) that Congress and the interest groups pressing for federal air pollution control simply had no interest in efficiency-enhancing economic instruments. Alternatively, it may suggest that in the 1970s the transaction costs of shifting regulatory regimes may have been too high relative to the benefits to be gained. ⁿ⁷⁵

When Congress enacted the 1970 Clean Air Act, it was operating under severe information constraints. Precious little information was available about the economic costs of pollution and the economic benefits of pollution control. (Any estimates were exceptionally rough and subject to great uncertainties.) Later studies have attempted, with the aid of hindsight, to calculate the costs and benefits of the Clean Air Act. Portney assessed and compared various studies to estimate the total costs and benefits of federal air pollution control between 1970 and 1981. His analysis suggests that the benefits of air pollution control during that period exceeded costs by more than \$ 26.3 billion. Portney cautioned, however, that the costs of additional increments of air pollution control should have risen sharply since 1981, "much faster than benefits could have been expected to increase." ⁿ⁷⁶

Portney's prediction reflects a belief that marginal benefits fall as the quantity of pollution control increases, while the marginal cost curve rises steeply. The same supposition is reflected in Figures 1-6 of this Article, all of which display downward sloping marginal benefit curves and upward sloping marginal cost curves. But in fact the actual benefits of the Clean Air Act have not only continued to rise since 1981, they have risen at a faster rate than total costs. This suggests either that Portney was incorrect about the shape or position of the curves post-1981, or more likely, that he presumed that marginal cost and benefit curves were static when they were not. In fact, both of these curves have shifted during the history of the Clean Air Act. As Portney expected, marginal costs increased - increments of control are more costly today [*917] than they were twenty years ago. But benefits increased even more. Apparently, the marginal benefit curve shifted upward even more than the marginal cost curve, as additional and more highly valued benefits accrued from reduced air pollution.

Whatever the explanation, the evidence is clear that the Clean Air Act has provided increasing net benefits to society throughout its history. Between 1981 and 1990, annualized and inflation-adjusted compliance costs rose by 17%, from \$ 20.9 billion to \$ 25.3 billion. ⁿ⁷⁷ During this period, emissions of all "criteria" air pollutants ⁿ⁷⁸ fell and air quality improved significantly. National emissions of criteria pollutants, excluding lead, declined by an average of 11.2%; the average reduction jumps to 24% if lead is included because lead emissions fell by 87% between 1981 and 1989. ⁿ⁷⁹ Thanks to these emissions reductions, national ambient concentrations of criteria pollutants fell between 1981 and 1988 by an average of 22.6% (only 10.6% if lead is excluded). ⁿ⁸⁰

The EPA has priced many of the benefits of emissions and ambient concentration reductions under the 1970 Clean Air Act. Its mean estimate of benefits (in constant 1990 dollars) grew from \$ 355 billion in 1975, to \$ 930 billion in 1980, to more than \$ 1.2 trillion in 1990. ⁿ⁸¹ In fact, the increase in total benefits exceeded by a substantial margin (both nominally and in percentage terms) the increase in the costs of complying with Clean Air Act regulations. Contrary to the prevailing wisdom, the 1970 Clean Air Act's predominantly command-and-control regulatory regime grew increasingly efficient between 1970 and 1990, producing far more benefits than

costs for society. Indeed, according to the EPA, the "net, direct, monetized benefits" of the Clean Air Act, 1970 to 1990 "ranged from 4.3 to 28.2 trillion dollars, with a central estimate of 13.7 [*918] trillion dollars."ⁿ⁸² Whether or not this central estimate is accurate, the important point for present purposes is that the Clean Air Act has continued to produce some level of net social benefits throughout its history. In a recent interview, Paul Portney asserted that any analysis of the Act would conclude that its benefits outweigh its costs.ⁿ⁸³ And after conducting an extensive review of the literature, Davies and Mazurek concur: "Taken as a whole, the benefits of the Clean Air Act seem clearly to outweigh the costs."ⁿ⁸⁴

Still, according to the "conventional story" outlined earlier in this Section, the Clean Air Act would have been more efficient (i.e., would have produced greater net benefits for society), had it relied from inception on more flexible market-based approaches. But that story ignores significant economic, institutional, and technological constraints that existed when Congress enacted the 1970 Clean Air Act. To be accurate, any comparison of costs and benefits must include an assessment of the transaction costs that such a large-scale shift in regulatory regimes would have entailed. And there is no question that a shift from a predominantly command-and-control regime to a market-based system would have entailed substantial, perhaps prohibitive, transaction costs. This is most obviously true with respect to costs of monitoring and enforcement, which tend to be higher for market-based programs, such as emissions trading, than for command-and-control regulations.

Monitoring, enforcement capabilities, and costs were among Congress's primary concerns when it enacted the Clean Air Act in 1970. The legislative history is replete with reports, hearings, and statements concerning deficiencies in air-pollution monitoring.ⁿ⁸⁵ According to a report by the NAPCA, for example, air-pollution monitoring equipment and "analytical techniques" available in 1970 were "not adequate to meet current and anticipated future needs in air monitoring, source testing, measurement of meteorological parameters, and laboratory research."ⁿ⁸⁶ Nationwide in 1970 there were 245 particulate matter (dust) monitors, 86 sulfur dioxide monitors, 82 carbon monoxide monitors, 43 nitrogen oxide [*919] monitors, and only 1 monitor for ozone.ⁿ⁸⁷ These monitors and other available analytical equipment "lacked accuracy, sufficient sensitivity to reflect progress in controlling air pollution, or the specificity needed to satisfy air quality criteria requirements."ⁿ⁸⁸

Point-source emissions monitoring was in an even less satisfactory state than ambient concentration monitoring. In the late 1960s, the government requested that industries self-monitor (to the extent possible) and report on their emissions rates. According to the NAPCA:

In large measure, industry response to such requests [was] good, but there have been instances of refusal to provide requested information. Often, information [was] refused on the ground that it [did] not exist or because assembling it would [have been] an undue burden on the company. There [were] cases, however, in which refusal seemingly reflected an unwillingness to cooperate.ⁿ⁸⁹

This confirmed the need for independent government monitoring to ensure compliance with pollution-control requirements.

Congress was also concerned with inadequate staffing of the state administrative agencies charged with implementing federal and state air pollution regulations. According to a 1970 report to Congress by the Department of Health, Education and Welfare (HEW), "control agencies" were "in general ... inadequately staffed. Fifty percent of State agencies [had] fewer than 10 positions budgeted, and 50 percent of local agencies [had] fewer than seven positions budgeted."ⁿ⁹⁰ The HEW report went on to note that state and local agency staffing would have to be increased by 300% in order "to implement the Clean Air Act properly."ⁿ⁹¹ According to Senator Muskie (the 1970 Clean Air Act's chief sponsor in the Senate), federal agency staffing would need to be almost tripled within three years [*920] to implement the Act fully.ⁿ⁹² To meet the demand for environmental protection experts, the federal government provided sizeable "training grants" to dozens of academic institutions during the late 1960s and into the 1970s.ⁿ⁹³

The deficiencies in available monitoring equipment and agency staffing could lead one to wonder how any regulatory program to reduce air pollution got off the ground. But the 1970 Clean Air Act was designed in a way that minimized these limitations. Specifically, by focusing on technological installations to reduce pollution emissions from new stationary sources and cars, the federal government could minimize monitoring and staffing deficiencies. As noted in Part III, as long as pollution control technologies were installed and operating, the government could be assured of some emissions reductions. A year before Congress enacted the Clean Air Act, Hagevik wrote, "The advantage of [direct regulation] is that it permits the government to take interim steps even though it has almost no idea of relevant measurements."ⁿ⁹⁴ By contrast, under an effluent tax system or tradable permit scheme, frequent and precise emission monitoring would have been necessary to accurately assess taxes or ensure compliance with permit quotas, which change with each allowance trade.ⁿ⁹⁵ Federal, state, or local officials certainly stood a better chance of ensuring that pollution-control technologies were installed and operating than of determining emissions rates from tens of thousands of stationary sources - let alone millions of automobiles.ⁿ⁹⁶

Continuous monitoring of emissions was simply not feasible in 1970 because of technological and personnel constraints.ⁿ⁹⁷ According to a 1967 report by the Working Committee on Economic Incentives of the Federal Coordinating Committee on the Economic Impact of Pollution [*921] Abatement, "Emission charges and effluent fees are not now entirely feasible and must await the development of adequate institutions, improved monitoring methods, and better pollution damage estimates."ⁿ⁹⁸ In 1969 the economist Harold Wolozin concluded that "formidable detection and monitoring problems are implicit in effluent fee schemes, a problem compounded by the primitive state of technology in these areas."ⁿ⁹⁹ He quoted from a presentation William Vickrey made at the 1967 annual meeting of the Air Pollution Control Association:

The real problem which advocates of effluent charges must face is the problem of metering, or of estimating in some way the amount of effluent actually generated by various emitters. Here the problem of air pollution is seen to be a particularly difficult one in that the number of small emitters and of the emitters difficult to meter effectively is large and their contribution to the problem is too great to be ignored. ⁿ¹⁰⁰

Paul Gerhardt, writing in 1969, agreed that "a fee system could be exceedingly difficult and costly to administer... Emission measurement technology is presently inadequate to meet the requirement that a regulatory agency be able to determine with some precision just how much an individual polluter is contributing to the atmospheric burden." ⁿ¹⁰¹ Consequently, regulatory approaches such as effluent taxes and tradable emissions allowances that were heavily dependent on regular and precise monitoring were impracticable.

In this respect, the 1970 Clean Air Act appears to be a real-world instantiation of Case 3 from Part IV.C. As in that hypothetical case, neither tradable permits nor effluent taxes were a feasible policy option for air pollution control in 1970 because of prohibitive monitoring costs. They may have been efficient in theory - more efficient, perhaps, than the command-and-control mechanisms that Congress actually codified - but only if those monitoring costs were ignored. Indeed, as noted in Part I, many of the economists who have written about the superior efficiency of effluent taxes and tradable emissions permits have ignored implementation and monitoring costs. Given that continuous emissions [*922] monitoring would have been necessary to assess taxes accurately or determine compliance with emissions quotas (pursuant to an emissions trading scheme); and given the unfeasibility of continuously monitoring emissions from individual smokestacks and tailpipes in 1970; it was rational - indeed, efficient - for Congress to rely on command-and-control regulations.

It should be noted, however, that almost from the first day after the 1970 Clean Air Act was enacted, Congress, President Nixon, and the EPA all began exploring incrementally more efficient means of attaining the Act's pollution-control goals. Indeed, the entire subsequent history of federal air pollution control can be viewed as a slow and inconsistent but deliberate evolution toward greater regulatory efficiency - an evolution that gained momentum as abatement costs increased and monitoring costs decreased with the improved quality, availability, and price of monitoring technologies.

Before the 1970 Clean Air Act was a year old, President Nixon proposed a "Clean Air Emission Charge" on sulfur dioxide emissions and a tax on lead additives in gasoline. ⁿ¹⁰² Neither of these proposals was adopted, although Congress held hearings on Nixon's proposed sulfur dioxide emissions charge (at which the EPA Administrator Russell Train testified strongly in favor of the charge). ⁿ¹⁰³

President Nixon created the EPA in 1970 by executive order to implement the new Clean Air Act. By 1972 the EPA began to introduce "economic" instruments of its own device. In fact, the EPA displayed a surprisingly rapid economic learning curve for a large government bureaucracy that, at its inception, had little economic expertise. ⁿ¹⁰⁴ Within [*923] its first decade of

existence the Agency innovated (under questionable statutory authority) four mechanisms designed to enhance the Clean Air Act's efficiency by increasing its flexibility, thereby reducing compliance costs for regulated industries: offsets, bubbles, netting, and banking.ⁿ¹⁰⁵ Congress eventually codified these programs in the 1977 Clean Air Act Amendments. In fact, they constituted the sum total of "market"-based regulations enacted in those Amendments.ⁿ¹⁰⁶ The two major new programs created in the 1977 Amendments were the nonattainment and PSD programs, both of which were discussed in the first part of this Section. These programs were based on the same command-and-control model upon which Congress relied in 1970.

Path dependence may have been a partial cause, given the high costs to all parties, including Congress, the EPA, and interest groups (regulated industries, environmental groups, etc.) of learning new regulatory approaches.ⁿ¹⁰⁷ According to Keohane et al., "Unfamiliar policy instruments may require legislators to spend time learning about them before they can provide substantial support, thereby giving rise to a status [*924] quo bias in favor of the current regime of command-and-control regulation."ⁿ¹⁰⁸ Similarly, regulated "firms may simply support the continuation of the status quo ... because replacing familiar policies with new instruments can mean the existing expertise within firms becomes less valued."ⁿ¹⁰⁹

But if path dependence is the explanation for the continuation of command-and-control instruments in the 1977 Clean Air Act Amendments, what does that signify? Some might conclude that the regulatory process, once headed down the path of command-and-control, was condemned to the inefficiencies of that approach (because of interest group formation, etc.). A neo-institutional or evolutionary approach, by contrast, might suggest simply that the costs of adopting alternative approaches, such as effluent taxes or marketable permits, were not yet worth the benefits.

In any case, by 1977 it was at least becoming more difficult for Congress and the EPA to justify their lack of attention to economic instruments purely on grounds of technological and economic constraints. Between 1970 and 1977 the total number of monitors for criteria air pollutants in use in the U.S. had increased by more than a factor of six; particulate matter monitors had increased in number from 245 (in 1970) to 1,120 (in 1975); ozone monitors increased from 1 to 321; and so on.ⁿ¹¹⁰ Moreover, the quality and reliability of the monitoring equipment and analytical techniques for data interpretation were improving. Still, a 1977 report by the National Research Council "identified the lack of statistical rigor in the design and analysis of most environmental monitoring networks."ⁿ¹¹¹ Monitoring technologies still were not available to permit the (cost-effective) wholesale substitution of market-based regulations for command-and-control. As Marc Roberts wrote in 1982:

When economists discuss such matters [as emissions trading] they sometimes talk as if monitoring devices were available to cheaply and reliably record the amount of all pollution emissions. If that were the case, decisions about whether a source had curtailed its pollution by the promised amount and whether a new source was emitting no more than the tradeoff transaction implied could be left to straightforward data [*925] gathering by an enforcement agent. Unfortunately, such monitoring devices typically are not available ...ⁿ¹¹²

But they soon would be.

Meanwhile, staffing deficiencies were substantially alleviated. As of 1979, the federal EPA had more than 500 employees nationwide working exclusively on clean air programs. States and local governments, meanwhile, devoted more than 6,500 personnel to air pollution control.ⁿ¹¹³ But whether this level of staffing was sufficient to meet the increased monitoring, data-collection, and record keeping needs of market-based regulatory programs is unclear. The lack of any history of environmental monitoring makes it difficult to assess accurately the effect of the technological and staffing constraints on environmental policy during the 1970s and 1980s. Nevertheless, the more than 3400 pages of legislative history that accompanied Congress's enactment of the 1977 Clean Air Act Amendments disclose that individual legislators were only marginally more interested in economic instruments in 1977 than in 1970, though they were, without doubt, better informed. At least the information was readily available to any legislator who chose to be informed.

In the course of floor debates over the 1977 Amendments, Senator Jake Garn mentioned a discussion he had with then-President Carter's chairman of the Council of Economic Advisers, Charles Schultze: "Mr. Schultze and I discussed the idea of pollution charges as an alternative to the absolute standards approach that has characterized so much of environmental protection in the United States in recent years. This is an approach which, it seems to me, deserves more attention than it has received."ⁿ¹¹⁴ To that end, Senator Garn inserted into the Congressional Record an article by Dr. Noel de Nevers entitled *Air Pollution Control Philosophies*. De Nevers's article pointed out the theoretical cost advantages of effluent taxes over command-and-control regulations, such as emissions standards.ⁿ¹¹⁵ Similarly, a report on the 1977 Clean Air Act Amendments by the House Interstate and Foreign Commerce Committee quoted a National Academy of Sciences study, which found that "an [*926] emissions charge appears to be a well suited policy instrument for inducing efficient sulfur emissions control... [and] would provide a powerful spur for the development of more efficient technologies"ⁿ¹¹⁶

Given that Congress was better informed of the potential cost savings of effluent taxes over traditional command-and-control regulations, what explains its collective decision in 1977 not to switch from a predominantly command-and-control regulatory regime to a more flexible system of effluent taxes or some other "economic" approach? Most economists and policy analysts, again, adopt a Public Choice explanation: Neither Congress, the EPA, the regulated industries, nor environmental groups favored a switch away from the familiar command-and-control regime.ⁿ¹¹⁷ No doubt that is part of the explanation. But often ignored is the fact, noted earlier, that the 1970 Clean Air Act's regulatory regime was achieving significant air pollution reductions while providing net economic benefits for the country. Consider the following accurate and balanced account from the legislative history of the 1977 Clean Air Act Amendments:

In the intervening 6 years [between enactment of the 1970 Clean Air Act and passage of the

1977 Amendments], significant progress has been achieved in meeting the Nation's air quality goals, although much remains to be done. Nationally, the air is cleaner now than it was in 1970. There has been a 25-percent decrease in atmospheric levels of sulfur oxides, and a decrease of more than 14 percent in particulates - the two major pollutants from industrial sources. Overall, new cars marketed today are 67 percent cleaner than those sold in 1970.

On the other hand, of the country's 247 air quality control regions, 188 remain out of compliance with the standards for particulates, 34 for sulfur dioxide, 70 for oxidants and carbon monoxide, and 16 for nitrogen oxide. Disturbingly, an analysis of these figures reveals that, although most of these areas surround large cities, some cities have even shown increases in pollution while significant amounts of air pollution continue to be measured in rural areas.

An industry-by-industry examination of the status of compliance with the Clean Air Act's requirements shows that although many facilities have been able to make the necessary adjustments, significant portions of many of them remain in violation of the law's requirements. Although there are some [927] 200,000 stationary sources of air pollution in the country, only 15,000 of the 20,000 major sources have been brought into compliance or placed on compliance schedules - and that most of these violators are the largest polluters and, presumably, those in the best position to come into compliance...

This is what must be weighed when we consider that 200 of the 480 coal-fired powerplants, 150 of the 200 steel complexes, 19 of 28 nonferrous smelters, 130 of 250 large refineries, 1,000 of 3,500 commercial boilers, and nearly half of the 320 municipal boilers in the country all remain in violation of the Clean Air Act.

Although the cost of pollution control is often cited by industry as being prohibitive, the cost of this program to date has not been excessive. Total national expenditures for air pollution control in 1975 were \$ 15.7 billion - around 1 percent of our total output of goods and services - and a rate which has been constant for the past several years - and less than is being spent on water pollution control. Meanwhile, it has been conservatively estimated that the cost of air pollution in health and material damage exceeds \$ 25 billion annually. ⁿ¹¹⁸

In the absence of information suggesting that the 1970 Clean Air Act was imposing excessive costs on society (relative to its benefits), what impetus could there have been for Congress to make the costly switch to some new and untested regulatory regime? No doubt the existing regime was not optimally efficient, but neither was it nominally inefficient: It produced benefits in excess of its costs. Nor was it nominally inefficient for Congress to choose in 1977 to continue along the same path. Indeed, no studies available to Congress in 1977 (and no studies completed since then) support the proposition that a market-based approach would have produced larger net social benefits for society in 1977 than the existing command-and-control regime after accounting for the costs of transition, including increased monitoring and other administrative costs.

Between 1977 and 1990 when Congress enacted its most recent set of Clean Air Act amendments, emissions and ambient concentrations of criteria pollutants continued to fall, ⁿ¹¹⁹ but at increased cost to society: Total annualized costs of air pollution control increased (in constant 1990 dollars) from \$ 15.9 billion in 1977 to \$ 26 billion in 1990. ⁿ¹²⁰ That is an increase of 63.5%. But costs did not rise faster than benefits, as Portney [*928] surmised. ⁿ¹²¹ To the contrary, the benefits of the Clean Air Act rose faster than the costs.

Figure 7 shows that the net benefit curve of federal air pollution control has been upward-sloping since Congress enacted the Clean Air Act in 1970. Between 1970 and 1975, the Act produced estimated net inflation-adjusted benefits - defined as the "mean monetized benefits less annualized costs for each year" - of \$ 341 billion. From 1975 to 1980, estimated net benefits nearly tripled to \$ 909 billion. They rose to \$ 1.13 trillion by 1985, and they stood at \$ 1.22 trillion by 1990. The rate of increase in net benefits diminished between 1970 and 1990 - rising by 166% between 1975 and 1980, by 25% between 1980 and 1985, and by only 8% between 1985 and 1990. But a deceleration in the rate of increase is not the same as a decrease. Throughout the twenty-year period benefits rose faster than costs. Between 1977 and 1990, as total costs rose by 63.5%, the net benefits of the Clean Air Act increased by 24.5%, despite the Act's continued heavy reliance on command-and-control mechanisms. ⁿ¹²²

One would not know this, however, from reading the legislative history of the Clean Air Act Amendments of 1990. The ten thousand pages of legislative history that accompanied the enactment of the 1990 Clean Air Act Amendments are replete with expressions of concern and debates over the respective costs and benefits of new and existing air pollution programs. ⁿ¹²³ But why, if the Clean Air Act was providing its greatest ever net benefits in 1990? There is no certain answer, but several factors may have played a role.

First, no one in 1990 really knew whether the Act was producing net costs or benefits; indeed, that is why Congress, in the 1990 Clean Air Act Amendments, ordered the EPA to undertake a cost-benefit analysis of the Act. ⁿ¹²⁴ But everyone knew that, whatever the benefits, the price tag of the Act was rising. ⁿ¹²⁵ Legislators may have mistakenly assumed, like

[*929]

Figure 7: Mean estimate of increase in net benefits of the Clean Air Act, 1970-1990, in billions of inflation-adjusted 1990 dollars. Source: Office of Air & Radiation, U.S. Env'tl. Protection Agency, *The Benefits and Costs of the Clean Air Act, 1970-1990*, at 56 tbl. 18 (1997)

[SEE FIGURE IN ORIGINAL]

Portney, ⁿ¹²⁶ that marginal costs were quickly overtaking marginal benefits. Had this actually been the case, it would have confirmed Hagevik's 1969 prediction that policy makers would become more interested in the costs of control "as the point of equality between incremental control costs and [*930] incremental damages is approached." ⁿ¹²⁷ But as already noted, in 1990 the Clean Air Act was still providing increasing net benefits. Nevertheless, in the legislative process, perception is as important as fact. Congressional interest in efficiency-enhancing

policies increased as legislators and others perceived that additional increments of pollution control could be obtained only at net cost to society.

But there is more to the story than congressional perceptions of the costs and benefits of air pollution control. By 1990 environmental abatement and monitoring technologies had improved to a point where economic instruments, such as effluent taxes and marketable pollution permitting, were finally becoming administratively feasible. Continuous emission monitors (CEMs), the first of which appeared just two years before Congress enacted the 1977 Clean Air Act Amendments, had become widely available and affordable by 1990. As Jahnke wrote in 1993, "CEM systems ... advanced considerably over the past 15 years, with improved sampling techniques, analyzers, and data processing systems being integrated to meet the challenges posed by new requirements."ⁿ¹²⁸ By 1991 the U.S. government was requiring continuous monitoring at twenty-four categories of sources subject to NSPSs under section 111 of the Clean Air Act. In addition, CEM was required for all electric power generators regulated under the acid rain program, which Congress created in the 1990 Clean Air Act Amendments.ⁿ¹²⁹ CEM systems were not yet available for all air pollutants and sources,ⁿ¹³⁰ but they made economic instruments a feasible (i.e., cost-effective) and, in some cases, preferable (i.e., more efficient) policy choice for certain combinations of pollutants and sources.

Meanwhile, the EPA was growing more open to the use of market mechanisms. The Agency had been preparing economic analyses (Regulatory Impact Analyses or RIAs) of its major regulations since its inception.ⁿ¹³¹ And it had grown comfortable with cost-benefit analysis as [*931] a tool of environmental policy. As a 1987 EPA report noted, "Environmentalists often fear that economic analysis will lead to less strict environmental regulations in an effort to save costs, but our study reveals that the opposite is just as often the case."ⁿ¹³² In addition, in 1987 the EPA wrapped up a small-scale and temporary but highly successful experiment in tradable rights to lead-content in gasoline.ⁿ¹³³ By the 1990s the EPA was employing more than 100 economists. All this gave the EPA greater economic expertise than any other federal health and safety agency.ⁿ¹³⁴ Heightened economic expertise, plus the increasing availability of advanced emissions monitoring technologies, may have made the EPA (and Congress) more comfortable with experimental economic approaches to pollution control, like emissions trading.

In addition, state environmental agencies were better staffed and equipped in 1990 than they had been in 1970 or 1977: "In constant 1992 dollars, air quality expenditures [by state agencies] went from \$ 249 million in 1971 to \$ 516 million in 1994."ⁿ¹³⁵ This may have alleviated federal concerns about the states' abilities to monitor and enforce federal environmental programs.

Given the increased information about market mechanisms for environmental protection, the innovation of new technologies to monitor emissions adequately, improved funding of state agencies, the development of agency economic expertise, and rising concern about the costs of environmental regulations, it is not particularly surprising that Congress, in the 1990 Clean Air Act Amendments, began experimenting on a larger scale with economic approaches such as emissions trading. Even though the Clean Air Act was continuing to yield net social benefits, the reasons for preferring command-and-control regulations over [*932] economic mechanisms - particularly concerning monitoring and enforcement - were waning. At least with respect to

certain specific air pollution problems, the theoretical advantages of market-based approaches could finally be realized.

The 1990 Amendments included the first large-scale experiment ever conducted with emissions trading in its new acid rain program.ⁿ¹³⁶ Senator Baucus, a primary sponsor of the 1990 Clean Air Act Amendments, clearly expressed the experimental nature of the program:

Many of the provisions in this bill are new ideas.

Allowance trading in the acid rain title. We think it will work. We thought it through as well as we could. We are not sure it will work as well as we had intended. Therefore, there will be many adjustments, modifications and refinements as we work with and experiment with the acid rain portion of this bill.ⁿ¹³⁷

Other legislators and President Bush referred to the emissions trading scheme as "innovative," "novel," and "never tried ... before."ⁿ¹³⁸

So far the experiment has worked better than anyone expected. By November 1995, 23 million sulfur dioxide allowances worth \$ 2 billion had been transferred in more than 600 market transactions.ⁿ¹³⁹ The first allowances sold in 1992 for between \$ 250 and \$ 400 a piece; the average fell to \$ 68 in 1996, but rebounded to \$ 107 in 1997.ⁿ¹⁴⁰ In addition to these transfers, many sources have saved and banked excess allowances for future use when further reductions are required beginning in the year 2000. The result has been a greater than expected reduction in sulfur dioxide emissions and a 10% to 25% reduction in acid precipitation in the Northeast.ⁿ¹⁴¹ Total emissions in 1995 were 5.3 million tons, 39% below the legislatively-set ceiling and more than 50% below 1980 emission levels.ⁿ¹⁴²

[*933] Economically, the acid rain program's sulfur dioxide emissions trading program has been "a terrific bargain,"ⁿ¹⁴³ producing substantial net benefits for society.ⁿ¹⁴⁴ The lowest estimates of its annual health benefits - \$ 12 billion - are four times higher than the highest estimates of annual program costs.ⁿ¹⁴⁵ A key question, of course, is whether the acid rain program's emission trading mechanism increased net benefits over what they would have been under direct regulation. Total cost savings are difficult to estimate, but must be substantial. Consider that just four utilities (Central Illinois Public Service, Illinois Power Company, Duke Power, and Wisconsin Electric Power Company) have estimated their aggregate savings from purchasing allowances rather than installing scrubbers at \$ 706 million.ⁿ¹⁴⁶ This figure is not far below the total annual costs of compliance with Phase I sulfur dioxide emission-reduction requirements, estimated at \$ 836 million.ⁿ¹⁴⁷

One important but oft-neglected point concerning the acid rain program is Congress's insistence on continuous emission monitoring "to preserve the orderly functioning of the allowance system, and ... ensure the emissions reductions contemplated by this [program]."ⁿ¹⁴⁸ This statutory

language reflects two critical perceptions. First, "unlike other control requirements of the Clean Air Act, utility emissions of sulfur dioxide and [nitrogen oxides] are capable of verification in a cost-effective manner through use of continuous emission monitors." Second, "the requirements for CEMS is the linchpin in this title for without good emissions data, a problem that has hampered enforcement of the Act to date, no allowance or emissions trading scheme can affectively [sic] operate." ⁿ¹⁴⁹ The implication is that absent the technical capability to precisely measure emissions "in a cost-effective manner," emission trading really cannot be said to be feasible, let alone more efficient than direct regulation. It is the existence of cost-effective technologies for [*934] measuring sulfur dioxide emissions that has made the emission trading program workable.

So far, the EPA's experiment in large-scale emission trading has been an unmitigated success from both environmental and economic perspectives. It proves that economic instruments in some cases can achieve environmental goals at less cost than direct regulation. And it marks an incremental evolution of federal air pollution control toward efficiency-enhancing economic instruments. ⁿ¹⁵⁰ It does not, however, signify a wholesale shift away from command-and-control.

Congress hardly forsook direct regulation in 1990. Not only did it maintain existing command-and-control programs; it even added some new ones. In fact, one of those new programs was more dubious economically than just about anything Congress had ever before enacted. Section 249 of the 1990 Clean Air Act Amendments required automakers to sell at least 150,000 "clean-fuel vehicles" (i.e., electric cars) per year beginning in 1996, and sales were to rise to 300,000 per year by 1999 - as if the industry could stipulate consumer preferences. ⁿ¹⁵¹ This exemplifies the claim from Part III that policies evolve only incrementally and nonuniformly in the wake of economic, institutional, and technological changes.

One question, however, remains: Have the 1990 Amendments on the whole increased, reduced, or not significantly affected the overall efficiency of the Clean Air Act? As Congress was considering the 1990 Clean Air Act Amendments, Portney predicted that their costs would exceed their benefits by between \$ 4 billion and \$ 30 billion per year. ⁿ¹⁵² But a recent empirical study by Hahn found that the benefits of all major (final) Clean Air Act regulations - twenty-five in all - promulgated by the EPA between 1990 and mid-1995 exceeded their costs by almost \$ 88 [*935] billion (although, on Hahn's numbers, only ten of them would have passed individualized cost-benefit tests). ⁿ¹⁵³ Can it be that the Clean Air Act is still growing more rather than less efficient, despite its continued heavy reliance on command-and-control regulations?

VI. Implications and Conclusion

According to the standard economic account, command-and-control regulations are inefficient, and should grow increasingly inefficient over time as additional pollution control becomes more costly. But the best available numbers on the Clean Air Act do not bear this out. Something must be wrong with either the numbers, the standard argument, or both.

No doubt the numbers are not perfect; estimations of environmental costs and especially environmental benefits are fraught with uncertainty and subjectivity, especially in the valuations

of non-priced goods and bads and the selection of discount rates. But it would take a clever accountant indeed to make the numbers show that the Clean Air Act imposes net costs on society. As the EPA has explained, "the benefits of the Clean Air Act and associated control programs [between 1970 and 1990] substantially exceeded costs. Even considering the large number of important uncertainties permeating each step of the analysis, it is extremely unlikely that the converse could be true."ⁿ¹⁵⁴ If the EPA's mean estimate of net benefits between 1970 and 1990 (\$ 21.7 trillion compounded at five percent)ⁿ¹⁵⁵ were too high by a factor of 100, the Clean Air Act still would have yielded \$ 217 billion in net social benefits.ⁿ¹⁵⁶ So, even if there is something terribly wrong with the numbers, there must also be something wrong with the claim that command-and-control is an inherently inefficient policy tool.

Specifically, standard economic accounts of the comparative efficiency of alternative regulatory regimes are insensitive to historical, institutional, and technological contexts. Most importantly, they tend to assume "perfect (and, incidentally, costless) monitoring,"ⁿ¹⁵⁷ or they assume that monitoring costs are the same regardless of the control [*936] regime that is chosen. As shown in this Article, both of these assumptions are unrealistic, and they often skew comparative cost-benefit analyses of alternative regulatory regimes. When institutional and technological costs are considered, command-and-control regulations appear neither inherently inefficient nor invariably less efficient than theoretical economic approaches, such as effluent taxes or emissions trading schemes. Indeed, in some cases, such as those involving very high monitoring costs, command-and-control can be more efficient than market mechanisms.ⁿ¹⁵⁸ However, the goal of this study has not been to question the efficiency-enhancing potential of effluent taxes or emissions trading programs. Indeed, as demonstrated in Part V, the Clean Air Act's large-scale experiment with emissions-trading in the acid rain program has been an unmitigated success, producing greater than expected emissions reductions at lower than expected cost. This success story will undoubtedly encourage Congress and the EPA to use economic instruments more widely in the future. Indeed, many are now calling on Congress to transform radically environmental policy, advocating abandonment of command-and-control in favor of the "next generation" of efficiency-enhancing market-based controls.ⁿ¹⁵⁹

Rena Steinzor has cautioned against such a radical transformation: "Without dramatically expanding the resources available to federal and state regulators, and without placing challenging, new demands on pollution sources to track emissions and research their toxicological effects, the shift to the 'next generation' of regulatory policy is likely to result in severe degradation of environmental quality."ⁿ¹⁶⁰ This Article's analysis suggests that caution is, indeed, warranted. As demonstrated here, command-and-control mechanisms have reduced air pollution, and they have done so (for the most part) efficiently. Moreover, market-based solutions are not well-suited for all institutional and technological contexts, particularly where monitoring costs are exorbitant. In that circumstance, command-and-control regulations may be both more effective and more efficient. To the extent they are replaced by market mechanisms, it should only be after careful, case-by-case examinations of [*937] expected costs and benefits, including implementation and monitoring costs.

On the other hand, this analysis also suggests that the radical policy changes Steinzor fears are unlikely to occur. Like other institutions in society, those of environmental protection (including the regulatory regime itself) tend to evolve slowly, incrementally, and inconsistently. And in this

case there is no reason to anticipate deviation from that tendency because the current Clean Air Act continues to provide substantial and apparently increasing net benefits for society. Consequently, there is little substantive (as opposed to political or ideological) reason for Congress radically to amend the Act. ⁿ¹⁶¹

Not all environmental laws have been as efficient as the Clean Air Act. By all accounts, the costs of the Clean Water Act (another predominantly command-and-control regime), for example, have outweighed its benefits. ⁿ¹⁶² But it is one thing to note that command-and-control-based regulatory regimes are sometimes inefficient; it is another to assert that they are inherently so. ⁿ¹⁶³ This Article does not dispute the former assertion, but the analysis suggests that the later assertion is erroneous.

So the question becomes, how and when should policy makers employ command-and-control rather than market mechanisms? As Stavins notes, "There is no simple answer, no policy panacea. Inevitably, case-by-case examinations are required." ⁿ¹⁶⁴ In large measure, the choice of regulatory regime depends on the goals and concerns of policy-makers. ⁿ¹⁶⁵ However, the analysis of this Article suggests that where abatement costs are relatively low and monitoring costs are relatively high, command-and-control is likely to be at least as efficient and effective as effluent taxes or a tradable emissions program. In the obverse case of relatively high abatement costs and relatively low monitoring costs, market mechanisms are likely to be more efficient. Of course, there are many other economic, institutional, and technological [*938] variables that can affect the comparison of regulatory options, which is precisely why case-by-case examinations are required.

Legal Topics:

For related research and practice materials, see the following legal topics:
Energy & Utilities Law Conservation Energy Policy & Conservation Act Fuel Economy Standards Environmental Law Air Quality General Overview Tax Law Excise Taxes Fuels (IRC secs. 4041-4042, 4081-4084, 4091-4093, 4121) General Overview

FOOTNOTES:

n1. See T.H. Tietenberg, Emissions Trading: An Exercise in Reforming Pollution Policy 38 (1985) [hereinafter Tietenberg, Emissions Trading]; Richard B. Stewart, United States Environmental Regulation: A Failing Paradigm, 15 J.L. & Com. 585, 587 (1996). "Command-and-control" is in essence a regulatory approach whereby the government "commands" pollution reductions (e.g., by setting emissions standards) and "controls" how these reductions are achieved (e.g., through the installation of specific pollution-control technologies). As used throughout this Article, the term "command-and-control" is synonymous with "technology-based command-and-control."

n2. See Bruce A. Ackerman & Richard B. Stewart, Reforming Environmental Law, 37 Stan. L. Rev. 1333, 1334 (1985); Richard B. Stewart, Models for Environmental Regulation: Central

Planning Versus Market-Based Approaches, 19 B.C. Env'tl. Aff. L. Rev. 547, 547 (1992) [hereinafter Stewart, Models for Environmental Regulation]; Richard B. Stewart, Environmental Regulation and International Competitiveness, 102 Yale L.J. 2039, 2087 (1993) [hereinafter Stewart, Environmental Regulation and International Competitiveness]; Cass R. Sunstein, Free Markets and Social Justice 276 (1997).

Pejorative labels like "Soviet-style" and "socialist central planning" are little more than convenient and ideologically-loaded substitutes for real arguments about the (de)merits of command-and-control. American command-and-control regulations are not comparable to "Soviet-style" regulations or, more generally, to the political-economic institutions of Marxism-Leninism. But see *infra* note 151 and accompanying text. For one thing, the label "Soviet-style" cannot legitimately be applied to regulatory programs duly enacted by democratically-elected legislatures or parliaments operating according to the rule of law. For another, the phrase "socialist central planning" denotes a non-market economy directed in its entirety by state planners. Command-and-control environmental regulations in advanced industrial democracies, however, typically restrict only a fraction of the activities occurring within predominantly market-driven economies; they do not replace but delimit markets.

n3. Throughout this Article, we use the labels "economic instruments" and "market-based approaches" to regulation interchangeably, in contrast to "command-and-control." For a primer on the various instruments that fall into these categories, see Robert Stavins & Bradley W. Whitehead, *The Next Generation of Market-Based Environmental Policies* 2-9 (Resources for the Future Discussion Paper No. 97-10, 1996).

n4. Geoffrey M. Hodgson, Economic Evolution: Intervention Contra Pangloss, 25 *J. Econ. Issues* 519, 524 (1991).

n5. See T.H. Tietenberg, Economic Instruments for Environmental Regulation, in *Economic Policy Towards the Environment* 86 (Dieter Helm ed., 1991) [hereinafter Tietenberg, *Economic Instruments*].

n6. See Walter O. Spofford, Jr., Efficiency Properties of Alternative Source Control Policies for Meeting Ambient Air Quality Standards: An Empirical Application to the Lower Delaware Valley (Resources for the Future Discussion Paper No. D-118, 1984).

n7. See, e.g., Adele R. Palmer et al., Economic Implications of Regulating Chlorofluorocarbon Emissions from Nonaerosol Applications (Rand Corp. Rep. No. R-2524-EPA, 1980); F. Roach et al., Alternative Air Quality Policy Options in the Four Corners Region, 1 *Sw. Rev.* 29 (1981); Alan J. Krupnick, Costs of Alternative Policies for the Control of Nitrogen Dioxide in Baltimore, 13 *J. Env'tl. Econ. & Mgmt.* 189, 190 (1986); Eugene P. Seskin et al., An Empirical Analysis of Economic Strategies for Controlling Air Pollution, 10 *J. Env'tl. Econ. & Mgmt.* 112, 114 (1983); Michael T. Maloney & Bruce Yandle, Estimation of the Cost of Air Pollution Control Regulation, 11 *J. Env'tl. Econ. & Mgmt.* 244, 255 (1984).

n8. Spofford, *supra* note 6, at 110-11.

n9. See Spofford, *supra* note 6; Scott E. Atkinson & Donald H. Lewis, A Cost-Effectiveness Analysis of Alternative Air Quality Control Strategies, 1 J. Envtl. Econ. & Mgmt. 237 (1974); Krupnick, *supra* note 7, at 192.

n10. Palmer et al., *supra* note 7, at 255.

n11. See Roach et al., *supra* note 7, at 52, 56.

n12. See Robert W. Hahn & Roger G. Noll, Designing a Market for Tradable Emissions Permits, in Reform of Environmental Regulation 119, 143-44 (Wesley A. Magat ed., 1982).

n13. Seskin et al., *supra* note 7, at 119.

n14. Maloney & Yandle, *supra* note 7, at 246-47.

n15. See Tietenberg, Economic Instruments, *supra* note 5, at 95.

n16. David L. Greene, CAFE or Price? An Analysis of the Effects of Federal Fuel Economy Regulations and Gasoline Price on New Car MPG, 1978-89, 11 Energy J. 37, 37 (1990); see also Amihai Glazar & Charles Lave, How Regulations Can Succeed Where Taxes Do Not: An Examination of Automobile Fuel Efficiency (Economic Working Paper No. ewp-pe/9406002, 1994), available at <<http://econwpa.wustl.edu/eprints/pe/papers9406/9406002.abs>>.

n17. The phrases "prevailing view" and "conventional wisdom," as used throughout this Article, refer to the prevailing views and conventional wisdom of law and economics scholars writing about environmental regulation over the past 25 years or so.

n18. J. Clarence Davies & Jan Mazurek, Pollution Control in the United States: Evaluating the System 15 (1998); see also David M. Driesen, Is Emissions Trading an Economic Incentive Program? Replacing the Command and Control/Economic Incentive Dichotomy, 55 Wash. & Lee L. Rev. 289 (1998) (arguing generally that the traditional distinction between command-and-control regulations and so-called "economic" instruments is misguided).

n19. Davies & Mazurek, *supra* note 18, at 15.

n20. In economists' terms, a given regulatory regime may be Kaldor-Hicks (or potentially Pareto) improving but not Kaldor-Hicks optimal. A given (re-)allocation of entitlements is "Kaldor-Hicks efficient" if those who gain from the (re-)allocation could afford (theoretically) to compensate the losers and still have a net profit from the (re-) allocation, and the losers from the (re-)allocation could not afford to offer the gainers enough to agree to forego their gains. For further discussion of the Kaldor-Hicks efficiency criterion, see, e.g., Nicholas Mercurio & Steven G. Medema, Economics and the Law: From Posner to Post-Modernism 50 (1997). Some economists reject the Kaldor-Hicks efficiency criterion because it is "easily manipulated and invites public policy error." Oliver E. Williamson, Deregulatory Takings and Breach of the Regulatory Contract: Some Precautions, 71 N.Y.U. L. Rev. 1007, 1009 (1996). These criticisms are accurate, but as Cooter and Ulen point out, the Kaldor-Hicks criterion remains "indispensable

to applied welfare economics." Robert Cooter & Thomas Ulen, *Law and Economics* 51 (1988). Presently, there is no preferable alternative criterion for determining the efficiency of public policy changes (including the theoretically pure but highly unrealistic Pareto efficiency criterion, which would require compensation even for regulatory regimes designed only to internalize externalities).

n21. See, e.g., Stewart, *Models for Environmental Regulation*, supra note 2.

n22. At least a few economists have recognized this. See, e.g., Glazar & Lave, supra note 16; Clifford S. Russell & Philip T. Powell, *Choosing Environmental Policy Tools: Theoretical Cautions and Practical Considerations* (1996).

n23. See Robert W. Hahn & Robert N. Stavins, *Incentive-Based Environmental Regulation: A New Era from an Old Idea?*, 18 *Ecology L.Q.* 1, 27 (1991).

n24. See id. at 4-5; Arnold W. Reitze, Jr., *Environmental Policy - It Is Time for a New Beginning*, 14 *Colum. J. Env'tl. L.* 111, 113 (1989).

n25. See Michael T. Maloney & Robert E. McCormick, *A Positive Theory of Environmental Quality Regulation*, 25 *J.L. & Econ.* 99 (1982).

n26. As Hodgson, supra note 4, at 528, notes, "Evolution is awesome and inspiring, but also messy, stupid and tragic." See also Samuel P. Hays, *The Future of Environmental Regulation*, 15 *J.L. & Com.* 549, 549-50 (1996) (noting, and approving of, the incremental nature of change in environmental policy).

n27. Martin L. Weitzman, *Prices vs. Quantities*, 41 *Rev. Econ. Stud.* 477, 479 (1974).

n28. This world should not be confused, however, with the real world or even a "Coasian world," which, in stark contrast to the world of the Coase theorem, are characterized by significant transaction costs. See Ronald H. Coase, *The Problem of Social Cost*, 3 *J.L. & Econ.* 1 (1960) [hereinafter Coase, *Social Cost*].

n29. Any residual externalities are efficient, i.e., the cost of correcting them would exceed the benefits. On the concept of efficient externality, see Harold Demsetz, *The Exchange and Enforcement of Property Rights*, 7 *J.L. & Econ.* 11 (1964).

n30. Even if the initial allocation of property rights were not optimally efficient, the perfectly functioning market would costlessly re-allocate them for optimal efficiency. See Coase, *Social Cost*, supra note 28.

n31. See id.

n32. As the Public Choice literature makes abundantly clear, governments fail too. Consequently, market failure alone cannot justify government intervention. As Coase notes, "It is no accident that in the literature ... we find a category 'market failure' but no category

"government failure.' Until we realize that we are choosing between social arrangements which are all more or less failures, we are not likely to make much headway." Ronald H. Coase, *The Regulated Industries: Discussion*, 54 *Am. Econ. Rev.* 194, 195 (1964). However, the issue of the propriety of government environmental intervention in imperfect markets is beyond the scope of this Article, which is merely concerned with the relative efficiency of alternative regulatory regimes. In other words, for purposes of this Article, some form of government intervention for environmental protection is presumed.

n33. We do not mean to suggest that benefit levels are precisely measurable after the fact of regulation, either, but that is not a necessary assumption for our analysis.

n34. The benefit function may be written, after Weitzman, *supra* note 27, as $B = B(y,a)$, where y equals the quantity of abatement and a is a set of random variables, which may be estimated only imperfectly before any regime can be put into effect. Weitzman, however, assumes linear cost and benefit curves. In contrast, we follow William D. Watson & Ronald G. Ridker, *Losses from Effluent Taxes and Quotas Under Uncertainty*, 11 *J. Envtl. Econ. & Mgmt.* 310 (1984), in assuming non-linear curves.

n35. That is, $B_{yy} < 0$.

n36. $C_{yy} > 0$.

n37. In any event, the area under the lowest marginal-benefit curve in Figure 2 is greater than the area under the highest marginal-cost curve.

n38. See Driesen, *supra* note 18, at 310-11; Office of Technology Assessment, *U.S. Congress Environmental Policy Tools: A User's Guide* 147, 151-53 (1995). The same is true for a system of effluent taxes. See *id.*; see also Frederick R. Anderson et al., *Environmental Improvement Through Economic Incentives* (1977); Robert M. Solow, *The Economist's Approach to Pollution and Its Control*, 173 *Science* 498 (1971).

n39. See Maloney & McCormick, *supra* note 25, at 106; Maloney & Yandle, *supra* note 7, at 247; Office of Technology Assessment, *supra* note 38, at 146-47; Frank S. Arnold, *Economic Analysis of Environmental Policy and Regulation* 229 (1995); Wesley A. Magat, *Introduction*, in *Reform of Environmental Regulation* 1, 5 (Wesley A. Magat ed., 1982); Sidney A. Shapiro & Thomas O. McGarity, *Not So Paradoxical: The Rationale for Technology-Based Regulation*, 1991 *Duke L.J.* 729, 749.

n40. See Clifford S. Russell et al., *Enforcing Pollution Control Laws* 3 (1986).

n41. See John Dales, *Policy Perceptions and Management Mechanisms*, in *Managing the Water Environment* 155 (Neil A. Swainson ed., 1976).

n42. Angela Frascini & Alberto Cassone, *Instrument Choice in Water Pollution Policy in Italy*, in *Economic Incentives and Environmental Policies* 89, 102 (Hans Opschoor & Kerry Turner eds., 1994).

n43. We say "could" rather than "would" because policy changes do not quickly, automatically, or uniformly track efficiency. A great deal of historical evidence demonstrates that inefficient (or less efficient) institutions and policies often survive for long periods of time. See, e.g., Douglass C. North, *Institutions, Institutional Change and Economic Performance* (1990).

n44. A budget constraint is said to be "soft" if a firm's survival does not depend on profits in the marketplace but rather on administrative and political considerations. A firm's budget constraint is said to be "hard" when costs and profits in the marketplace do determine its survival. See Janos Kornai, *The Soft Budget Constraint*, 39 *Kyklos* 3 (1986).

n45. The phrases "hard law constraint" and "soft law constraint," as analogues of hard and soft budget constraints, first appeared in Bartłomiej Kaminski and Karol Soltan, *The Evolution of Communism*, 10 *Int'l Pol. Sci. Rev.* 371, 385 (1989). This assumption of hard law constraints is relaxed in Case 5.

n46. See Daniel H. Cole, *Instituting Environmental Protection: From Red to Green in Poland* 238 (1998).

n47. See *id.* at 71, 152-53, 238. Stewart, *Models for Environmental Regulation*, *supra* note 2, ignores these institutional problems in recommending that former Soviet Bloc countries immediately adopt market mechanisms for environmental protection, rather than command-and-control instruments.

n48. See Cole, *supra* note 46.

n49. Errol Meidinger, *On Explaining the Development of "Emissions Trading" in U.S. Air Pollution Regulation*, 7 *Law & Pol'y* 447, 451 (1985).

n50. *Id.* at 452.

n51. Robert W. Hahn, *The Politics and Religion of Clean Air*, *Cato Rev. Bus. & Gov't*, Winter 1990, at 21 [hereinafter Hahn, *Clean Air*].

n52. Eric W. Orts, *Reflexive Environmental Law*, 89 *Nw. U. L. Rev.* 1227, 1236 (1995) (quoting James E. Krier, *The Irrational National Air Quality Standards: Macro-and Micro-Mistakes*, 22 *UCLA L. Rev.* 323, 323-35 (1974)).

n53. See *Lead Indus. Ass'n v. EPA*, 647 F.2d 1130, 1149 (D.C. Cir. 1980), cert. denied, 449 U.S. 1042 (1980).

n54. See Ackerman & Stewart, *supra* note 2, at 1335.

n55. See *id.* at 1335-36; David Harrison, Jr. & Paul R. Portney, *Making Ready for the Clean Air Act*, *Regulation Mar./Apr.* 1981, at 24, 27; Nathaniel O. Keohane et al., *The Positive Political Economy of Instrument Choice in Environmental Policy 2* (Resources for the Future Discussion Paper No. 97-25, 1997).

n56. See Ackerman & Stewart, *supra* note 2, at 1335-36; Stewart, *Environmental Regulation and International Competitiveness*, *supra* note 2, at 2063. Of course, polluting industries are not the only potential sources of pollution-control innovations. See Robert Repetto, *Air Quality Under the Clean Air Act*, in *Incentives for Environmental Protection* 221, 276-77 (Thomas C. Schelling ed., 1983). In fact, the NSPSs in the 1970 Clean Air Act created positive incentives for independent environmental protection industries to innovate new pollution-control technologies, which, if selected as the "best available technology adequately demonstrated," might capture entire markets. The 115.1 thousand companies comprising the U.S. environmental industry produced \$ 436 billion in global revenues and employed 1.3 million people in 1996. See U.S. Dep't of Commerce, *Environmental Industry of the United States* 1 (1997).

n57. According to Public Choice theory, political/ legislative processes operate like economic markets; that is, like market participants, participants in political/ legislative processes act to maximize their individual welfare rather than some more broadly conceived social welfare. The results of such processes, therefore, are best viewed not as the deliberative decisions of bodies dedicated to improving the public weal, but as the outcomes of contests for political largess between various interested groups of individuals. For more on Public Choice theory, see, e.g., Nicholas Mercuro and Steven G. Medema, *Economics and the Law: From Posner to Post-Modernism* ch.3 (1997).

n58. See 42 U.S.C. 7411 (1997).

n59. See Alliance for Clean Coal v. Bayh, 888 F. Supp. 924, 927 (S.D. Ind. 1995).

n60. For a thorough treatment of the conflict between eastern and western coal interests, see Bruce A. Ackerman & William T. Hassler, *Clean Coal/Dirty Air: Or How the Clean Air Act Became a Multibillion-Dollar Bail-Out for High-Sulfur Coal Producers and What Should Be Done About It* (1981). In the next part of this Section, we will carry the eastern versus western coal dispute through the 1990 Clean Air Act Amendments, when Congress reworked its entire approach to sulfur dioxide emissions from coal-fired power plants.

n61. See Sierra Club v. Ruckelshaus, 344 F. Supp. 253, 255-56 (D.D.C. 1972), affirmed by an equally divided Court, 412 U.S. 541 (1973). The story of how the Supreme Court came to affirm the district court's ruling is itself an interesting story. According to Justice Thurgood Marshall's notes, the Justices initially voted 5-3 to reverse the district court's decision, with Justice Marshall voting with the majority (Justice Powell did not participate in the case). But after reading Justice Douglas's hastily prepared draft dissent, which warned that the majority's ruling would permit significant levels of air pollution to be spread to pristine regions, Justice Marshall switched his vote, resulting in a tie that affirmed the lower court's decision. See Robert V. Percival et al., *Environmental Regulation: Law, Science, and Policy* 803-04 (2d ed. 1996).

n62. B. Peter Pashigian, *Environmental Regulation: Whose Self-Interests are Being Protected?*, 23 *Econ. Inquiry* 551, 553 (1985).

n63. See *id.*

n64. This is a domestic version of a common North versus South debate in international environmental law. See, e.g., John Ntambirweki, *The Developing Countries in the Evolution of an International Environmental Law*, 14 *Hastings Int'l & Comp. L. Rev.* 905 (1991).

n65. See, e.g., Harrison & Portney, *supra* note 55, at 25.

n66. Hahn, *supra* note 51, at 21.

n67. Orts, *supra* note 52, at 1236.

n68. See Ackerman & Stewart, *supra* note 2, at 1338; Tietenberg, *Emissions Trading*, *supra* note 1, at 39-56.

n69. See Office of Air & Radiation, U.S. Env'tl. Protection Agency, *The Benefits and Costs of the Clean Air Act, 1970-1990* (1997); Davies & Mazurek, *supra* note 18, at 278.

n70. Percival et al., *supra* note 61, at 772.

n71. See, e.g., North, *supra* note 43, at 93-95.

n72. Before 1970, these technology-and health-based standards were to be set by the states pursuant to Department of Health, Education and Welfare (HEW) recommendations. See Robert Martin & Lloyd Symington, *A Guide to the Air Quality Act of 1967*, at 13-16 (1968). A major failing of the 1967 Air Quality Act, corrected by the 1970 Clean Air Act, was the lack of clear federal authority to promulgate emissions standards in cases where the states failed to promulgate sufficient implementation plans of their own. See *id.* at 18-19. Of course, the 1970 Clean Air Act also federalized completely emissions limitations for new stationary sources.

n73. See, e.g., J.H. Dales, *Pollution, Property, and Prices* (1968).

n74. See Environmental Policy Div., Library of Congress, 93d Cong., 2d Sess., *A Legislative History of the Clean Air Act Amendments of 1970*, at 1223-24 (U.S. Senate Comm. on Pub. Works Print 1974) [hereinafter *Environmental Policy Div., 1970 Legislative History*]. There was also one mention of a possible subsidy to create positive incentives for auto makers to innovate new, cleaner cars. But this comment was made in reference to a separate legislative initiative, then before Congress but never enacted, which would have authorized the federal government to purchase "low-pollution cars for its own use," even if they were twice the price of conventional automobiles. *Id.* at 1503.

n75. It is worth noting in this context that Congress was not oblivious to the costs of the air pollution programs it established. In fact, in section 305(a) of the Clean Air Act, Congress required the Secretary of Health, Education and Welfare to provide Congress with annual studies of the costs to government and regulated entities of implementing air pollution control regulations. The Secretary submitted his report, *The Cost of Clean Air*, to Congress in March 1970. S. Doc. No. 91-65 (1970).

n76. Paul R. Portney, Air Pollution Policy, in Public Policies for Environmental Protection 27, 69 (Paul R. Portney ed., 1990) (hereinafter Portney, Air Pollution Policy). Portney's conclusion confirmed Freeman's earlier finding. See A. Myrick Freeman, III, Air and Water Pollution Control: A Benefit-Cost Assessment (1982).

n77. Of course, compliance costs comprise only a fraction (though perhaps the largest fraction) of the total costs of air pollution control.

n78. A "criteria" air pollutant is one for which the EPA has established national ambient air quality standards under the Clean Air Act. Today, there are six such criteria air pollutants, including particulate matter, sulfur dioxide, carbon monoxide, nitrogen oxides, ozone, and lead.

n79. It is worth noting that no single criteria pollutant experienced an increase in emissions during this period. Calculated from figures presented in Council on Env'tl. Quality, Executive Office of the President, Environmental Quality: The Twentieth Annual Report of the Council on Environmental Quality Together with the President's Message to Congress 470-72 tbls.42 & 43 (1990).

n80. See id. at 469 tbl.41.

n81. Office of Air & Radiation, supra note 69, at 56 tbl.18. In valuing the benefits, EPA valued a human death averted at \$ 4.8 million. Id. at ES-6 tbl.ES-3. This is "an average value from the literature." Davies & Mazurek, supra note 18, at 130. The EPA utilized a 5% (net of inflation) discount rate in computing annualized compliance costs; it also provided alternative computations utilizing 3% and 7% (net of inflation) discount rates. Office of Air & Radiation, supra note 69, at 8 tbl.1, A-15 tbl.A-8.

n82. See Office of Air & Radiation, supra note 69, at ES-9. The broad estimate range is due to EPA's inclusion of alternative valuations and discount rates. Note that EPA's estimate of costs included not only compliance costs but also effects on GNP and consumption. Id. at 11.

n83. See Alec Zacaroli, Air Pollution: Economist Blasts EPA Cost/Benefit Report for Clean Air Act; Others Support Agency, BNA Nat'l Env't Daily, Dec. 16, 1998, available in LEXIS, BNA Library, BNANED File.

n84. Davies & Mazurek, supra note 18, at 278.

n85. See Environmental Policy Div., 1970 Legislative History, supra note 74, at 253, 255, 736, 1094, 1212, 1301-07.

n86. Id. at 1306.

n87. See Office of Air & Radiation, supra note 69, at D-3 tbl.D-1.

n88. Environmental Policy Div., 1970 Legislative History, *supra* note 74, at 1306-07. For descriptions of the technologies available circa 1970 for air pollution monitoring, see Alvin Lieberman & Peter Schipma, *Air-Pollution-Monitoring Instrumentation: A Survey* (1969).

n89. Environmental Policy Div., 1970 Legislative History, *supra* note 74, at 1312. These problems continue to plague government reliance on industry self-monitoring. See U.S. Gen. Accounting Office, *Environmental Enforcement: EPA Cannot Ensure the Accuracy of Self-Reported Compliance & Monitoring Data* (U.S. Senate Comm. Governmental Affairs Print 1993) (focusing on self-monitoring problems under the Resource Conservation and Recovery Act and the Clean Water Act); Arnold W. Reitze, Jr., *Air Pollution Law* 931-32 (1995).

n90. Environmental Policy Div., 1970 Legislative History, *supra* note 74, at 254. The HEW was the federal agency charged with primary responsibility for environmental protection before President Nixon created the EPA in 1970.

n91. *Id.*

n92. See *id.* at 230.

n93. See Environmental Policy Div., 1970 Legislative History, *supra* note 74, at 1296.

n94. George Hagevik, *Legislating for Air Quality Management: Reducing Theory to Practice*, in *Air Pollution Control* 173, 180 (Clark C. Havighurst ed., 1969).

n95. See *id.* at 176-77; Office of Technology Assessment, *supra* note 38, at 147, 151-53.

n96. For instance, in the early 1970s the Los Angeles County Air Pollution Control District managed to inspect every major source for compliance once a month. See Daniel H. Willick & Timothy J. Windle, *Rule Enforcement by the Los Angeles County Air Pollution Control District*, 3 *Ecology L.Q.* 507 (1973). Not every state or local government was as diligent in enforcing compliance. See Paul B. Downing & James N. Kimball, *Enforcing Pollution Control Laws in the U.S.*, 11 *Pol'y Stud. J.* 55 (1982). But the point is that it was at least possible (at some finite cost) to inspect regulated polluters to ensure that pollution-control equipment was installed and properly operating.

n97. No continuous emission monitoring technologies were available in the United States prior to 1975. See James A. Jahnke, *Continuous Emission Monitoring* 2 (1993).

n98. Working Comm. on Econ. Incentives, Federal Coordinating Comm. on the Econ. Impact of Pollution Abatement, *Cost Sharing with Industry?* 36 (1967).

n99. Harold Wolozin, *The Economics of Air Pollution: Central Problems*, in *Air Pollution Control* 31, 39 (Clark C. Havighurst ed., 1969).

n100. Id. at 40 (quoting Willaim Vickrey, Theoretical and Practical Possibilities and Limitations of Market Mechanism Approach to Air Pollution Control (June 11, 1967) (paper presented at the Air Pollution Control Association Annual Meeting, Cleveland, OH)).

n101. Paul H. Gerhardt, Incentives to Air Pollution Control, in *Air Pollution Control* 162, 169 (Clark C. Havighurst ed., 1969).

n102. See Council on Env'tl. Quality, Executive Office of the President, *The President's 1971 Environmental Program* 27, 30 (1971). Evidently, President Nixon viewed his proposed charge on sulfur dioxide emissions as a second-best alternative to technology standards. No technologies were "available" at the time for controlling sulfur dioxide emissions. See id. at 27.

n103. See Environmental Policy Div., Library of Congress, 95th Cong., 2d Sess., *A Legislative History of the Clean Air Act Amendments of 1977: A Continuation of the Clean Air Act Amendments of 1970*, at 2541 (U.S. Senate Comm. on Env't & Pub. Works Print 1978) [hereinafter *Environmental Policy Div., 1977 Legislative History*]. A decade later in 1982, the EPA introduced a successful gasoline lead-content trading program. See Peter S. Menell & Richard B. Stewart, *Environmental Law and Policy* 417-18 (1994); see also *infra* note 130 and accompanying text.

n104. Moreover, during its first years the EPA

was unable to consider broad policy options and goals because it had to cope with changing political and economic circumstances. In 1970, the Agency faced public pressure to regulate without regard for cost. The national consensus in favor of environmental action, however, quickly dissolved with the appearance of the economic downturn and energy crisis of the early 1970s.

Alfred A. Marcus, *EPA's Organizational Structure*, 54 *Law & Contemp. Probs.* 5, 34 (1991). Richard Lazarus stresses the legal pressures on the EPA to implement lofty but vague statutory mandates "'to eliminate water pollution, end all risk from air pollution, prevent hazardous waste from reaching ground water, establish standards for all toxic drinking water contaminants, and register all pesticides,'" all within "extremely short deadlines," that "left little time for the EPA to develop the scientific and technological expertise necessary to defend its implementation of the laws from attack." Richard J. Lazarus, *The Neglected Question of Congressional Oversight of EPA: Quis Custodiet Ipsos Custodes (Who Shall Watch the Watchers Themselves)?*, 54 *Law & Contemp. Probs.* 205, 222 (1991) (quoting Council On Env'tl. Quality, *Sixteenth Annual Report* 14 (1985)).

n105. First, in 1974, the EPA adopted a "netting" policy that permitted firms to avoid expensive NSPSs by netting emissions from new or substantially modified sources with emission decreases from existing sources at the same facility. In late 1976, the Agency promulgated "offset"

regulations that permitted the construction of new sources in highly polluted nonattainment areas (that otherwise would be subject to construction bans), so long as all new emissions were offset by emission reductions from other sources in the area. Under the EPA's "bubble policy," adopted in 1979, regulated firms could reduce compliance costs by treating several point-sources of emissions at a single plant as a single source for purposes of determining compliance. Also in 1979, the Agency began allowing firms to "bank" excess emission reductions (that is, reductions in excess of those required under current standards) for later use, sale, or lease. See Richard A. Liroff, *Reforming Air Pollution Regulation: The Toil and Trouble of EPA's Bubble* (1986); Robert W. Hahn & Gordon L. Hester, *Marketable Permits: Lessons for Theory and Practice*, 16 *Ecology L.Q.* 361 (1989).

n106. The Senate bill also contained an instruction to the EPA to consider a fee of nitrogen oxide emissions to fund efforts to innovate new control technologies for that air pollutant. And the House bill contained a provision to require the EPA generally to investigate the feasibility of economic instruments as alternatives to command-and-control.

n107. See Steven Kelman, *What Price Incentives? Economist and the Environment* (1981); W.P. Welch, *The Political Feasibility of Full Ownership Property Rights: The Cases of Pollution and Fisheries*, 16 *Pol'y Sci.* 165 (1983).

n108. Keohane et al., *supra* note 55, at 39.

n109. *Id.* at 30 n.52 (citing Kelman, *supra* note 107; Richard B. Stewart, *Economic Incentives for Environmental Protection: Opportunities and Obstacles* (1996) (unpublished manuscript)).

n110. See Office of Air & Radiation, *supra* note 69, at D-3 tbl.D-1.

n111. Council on Env'tl. Quality, *supra* note 79, at 56 (citing 4 National Academy of Sciences, National Research Council, *Analytical Studies for the U.S. Environmental Protection Agency: Environmental Monitoring* (1977)).

n112. Marc J. Roberts, *Some Problems of Implementing Marketable Schemes: The Case of the Clean Air Act*, in *Reform of Environmental Regulation* 93, 99 (Wesley A. Magat ed., 1982).

n113. See National Comm'n on Air Quality, *To Breathe Clean Air* 94 tbl.4 (1981).

n114. See Environmental Policy Div., *1977 Legislative History*, *supra* note 103, at 1192.

n115. But, interestingly, de Nevers's article also pointed out that command-and-control (specifically emissions standards) "in its early days ... was an excellent philosophy. Most of the progress which has been made in air pollution since 1863 was made by the application of this philosophy." *Id.* at 1195.

n116. *Id.* at 2540 (quoting National Academy of Sciences, *Air Quality and Statutory Emission Control* 230-31 (1975)).

n117. See, e.g., Keohane et al., *supra* note 55.

n118. Environmental Policy Div., 1977 Legislative History, *supra* note 103, at 3050-51.

n119. See Council on Env'tl. Quality, *supra* note 79, at 469-72 tbls. 41-43.

n120. See Office of Air & Radiation, *supra* note 69, at A-16 tbl.A-9.

n121. See Portney, Air Pollution Policy, *supra* note 76, and accompanying text.

n122. Office of Air & Radiation, *supra* note 69, at 55, 56 tbl.18.

n123. For a sampling of some of these expressions of concern and debates, see Environment & Natural Resources Policy Div., Library of Congress, 103d Cong., 1st Sess., A Legislative History of the Clean Air Act of 1990, at 731, 1058, 1091, 1179, 1193, 4829, 7187, 9736-9755, 9826, 9867 (U.S. Senate Comm. on Env't & Pub. Works Print 1993) [hereinafter Environment & Natural Resources Policy Div., 1990 Legislative History].

n124. See 42 U.S.C. 7612 (1994).

n125. The legislative history of the 1990 Clean Air Act Amendments is filled with statements by legislators and outside studies and articles about the high costs of air pollution control. For example, Senator Symms introduced into the record two editorials: one from the Wall Street Journal entitled Clean Air Politics and another from the Washington Times entitled Forthcoming Clean Air Depression? See Environment & Natural Resources Policy Div., 1990 Legislative History, *supra* note 123, at 758-60. Senator Symms also inserted into the record a report by Robert Hahn and Wilbur Steger entitled Direct Economic Impacts of Proposed Clean Air Act Amendments: Jobs Lost and Jobs-at-Risk. See *id.* at 5653-62. A letter signed by, among others, James Buchanan, Milton Friedman, and George Stigler, advising then-President Bush to veto the Amendments because of their high cost, was inserted into the record and referred to on other occasions. See *id.* at 1179, 1345. Senator Dannmeyer inserted into the record several cost estimates, including the Bush Administration's cost estimate of the House and Senate bills, and a study by Bretton Sciaroni entitled The Cost of Clean Air published by a group calling itself Citizens Against Government Waste. See *id.* at 1351-90. Meanwhile, proponents of the legislation referred to studies showing the continuing high costs of air pollution to public health and resources. For example, Senator Baucus inserted in the record a letter from the American Lung Association estimating the total health-related costs of air pollution at \$ 100 billion. See *id.* at 4831-32. Senator Baucus also inserted a study by James S. Cannon The Health Costs of Air Pollution which noted that "the price tag of pollution [was] rising" as high as \$ 432 billion in health-care costs alone. *Id.* at 5083-5123. Baucus explained that "as scientists' ability to quantify the health impact of air pollution improves, the best guess of the cost of air pollution continues to increase." *Id.* at 5080. Might this explain why the net benefits of air pollution control have continued to rise into the 1990s, contrary to the expectations of many economists?

n126. See Portney, Air Pollution Policy, *supra* note 76, at 69.

n127. Hagevik, *supra* note 94, at 183 n.24.

n128. Jahnke, *supra* note 97, at 8.

n129. See *id.* at 12-13 tbl.2-1.

n130. For instance, in 1998 and 1999, the EPA was still working out the bugs in a continuous monitoring system for particulate-matter emissions from hazardous waste incinerators. See Amy Porter, Hazardous Waste: New PM Continuous Emission Data Show Problems With Monitoring Units, *BNA Nat'l Env't Daily*, June 29, 1998, available in LEXIS, BNA Library, BNANED File; see also Kip Betz, Air Pollution: Continuous Emission Monitoring Technology Falls Short on Particulates, Engineer Says, *BNA Nat'l Env't Daily*, June 23, 1999, available in LEXIS, BNA Nat'l Env't Daily File (noting that current CEMs for particulate matter are useful as "'an indicator of how well your process is working on an incinerator, or whatever sort of control device you have,'" but not as a compliance tool).

n131. The EPA's rules were first subject to "Quality of Life" reviews by President Nixon's Office of Management and Budget. U.S. Env'tl. Protection Agency, *EPA's Use of Benefit-Cost Analysis: 1981-1986*, at S-2 (1987). Subsequently, the Agency was required to perform economic analyses of major rules under executive orders issued by Presidents Carter, Reagan, and Clinton. See Davies & Mazurek, *supra* note 18, at 32.

n132. U.S. Env'tl. Protection Agency, *supra* note 131, at 2.

n133. As part of its phase-out of leaded gasoline from 1982 to 1987, the EPA temporarily allowed trading in "rights" to add lead to gasoline. Refiners that produced gasoline with less lead content than mandated by federal standards had a right to sell or bank the excess lead. Smaller refiners that could not afford to meet the federal lead-content standards were able to reduce their compliance costs by purchasing "lead rights" instead of reducing lead content. According to Hahn & Hester, *supra* note 105, at 380-91, EPA's lead-trading program was highly successful. "The market in lead rights was very active, and ... this activity generally increased throughout the life of the program... The costs savings to refiners from lead rights trading and banking ... amounted to hundreds of millions of dollars." *Id.* at 386-87. But one important reason for this program's success neglected by Hahn and Hester is that, unlike fugitive emissions from smokestacks, lead content remains fairly constant in gasoline, where it can be measured at any time, thus facilitating compliance enforcement. Nevertheless, this successful early experiment with emissions trading undoubtedly increased the EPA's confidence with emissions trading as a policy tool.

n134. See Davies & Mazurek, *supra* note 18, at 32.

n135. *Id.* at 42.

n136. See 42 U.S.C. 7651 (1997).

n137. Environment & Natural Resources Policy Div., 1990 Legislative History, supra note 123, at 1142.

n138. Id. at 727, 1144, 1269, 2550, 3389, 4857, 6391. On the "experimental" nature of emissions trading and other "new" approaches to environmental protection, see Daniel P. Selmi, Experimentation and the "New" Environmental Law, 27 Loy. L.A. L. Rev. 1061 (1994).

n139. Each allowance equals one ton of sulfur dioxide. See 42 U.S.C. 7651(a)(3) (1997).

n140. See Percival et al., supra note 61, at 831-32; Alec Zacaroli, Air Pollution: Acid Rain Allowance Auction Generates \$ 32 Million in Sales; Prices Up Dramatically, BNA Chemical Reg. Daily, March 28, 1997, available in LEXIS, BNA Library, CHEMRG File.

n141. See Byron Swift, The Acid Rain Test, Env'tl. F., May-June 1997, at 16, 17.

n142. See Alec Zacaroli, Leading the News: Air Pollution: Utilities Achieve 100 Percent Compliance with EPA Acid Rain Program, Report Says, BNA Daily Env'tl. Rep., Aug. 12, 1996, available in LEXIS, BNA Library, BNANED File.

n143. Percival et al., supra note 61, at 832.

n144. See Dallas Burtraw et al., The Costs and Benefits of Reducing Acid Rain 26 (Resources for the Future Discussion Paper No. 97-31-REV, 1997).

n145. See Percival et al., supra note 61, at 832. It is worth noting that these benefit estimates of the acid rain program do not include difficult-to-quantify environmental benefits, such as reduced acid rain damage to forests, lakes, rivers, and buildings.

n146. See U.S. Gen. Accounting Office, Air Pollution: Allowance Trading Offers an Opportunity to Reduce Emissions at Less Cost 33-34 (1994).

n147. See Energy Info. Admin., The Effects of Title IV of the Clean Air Act Amendments of 1990 on Electric Utilities: An Update 12 (1997).

n148. 42 U.S.C. 7651k(a) (1997).

n149. Environment & Natural Resources Policy Div., 1990 Legislative History, supra note 123, at 1040.

n150. That incremental shift is also reflected in some other initiatives enacted as part of the 1990 Clean Air Act Amendments that have not received as much attention as the acid rain program. For example, Congress expressly authorized the states to utilize "economic incentives such as fees, marketable permits, and auctions of emissions rights" as control measures in their State Implementation Plans. 42 U.S.C. 7410(a)(2)(A) (1997). Congress further authorized states to use these same tools under the Clean Air Act's nonattainment area program. See id. 7502(c)(6). One market mechanism that did not make it into the final version of the 1990 Amendments was an

emissions fee on existing stationary sources in nonattainment areas. However, the purpose of the fee was not so much to reduce emissions as to provide revenue to cover the costs of administering the EPA or state agency programs. See Environment & Natural Resources Policy Div., 1990 Legislative History, *supra* note 123, at 6194, 8365, 8378, 8399-8400, 9467.

n151. 42 U.S.C. 7589(c)(1). Unlike most command-and-control environmental regulations, this requirement was truly reminiscent of socialist central planning, focusing on quantitative supply targets while completely ignoring the primacy of consumer demand. See *supra* note 2 and accompanying text.

n152. See Paul R. Portney, Economics and the Clean Air Act, 4 J. Econ. Persp., Fall 1990, at 179, reprinted in Environment & Natural Resources Policy Div., 1990 Legislative History, *supra* note 123, at 1361-69.

n153. See Robert W. Hahn, Regulatory Reform: What Do the Government's Numbers Tell Us?, in Risks, Costs, and Lives Saved: Getting Better Results from Regulation 208, 222 tbl.10-5 (Robert W. Hahn ed., 1996).

n154. Office of Air & Radiation, *supra* note 69, at ES-9.

n155. See *id.* at 56 tbl.18.

n156. We have not attempted in this Article to explain why air pollution control policy in general has been growing more rather than less efficient, despite its continued heavy reliance on command-and-control. As far as we are aware, no other study has even pointed out that this is the case, let alone explained it. Among the possible reasons are population growth, increasing health-care costs, and improvements in methodologies for calculating environmental costs and, particularly, benefits.

n157. Russell et al., *supra* note 40, at 3.

n158. Of course, high monitoring costs do not always render market-based approaches, such as effluent taxes, less efficient than command-and-control regulations. See Winston Harrington et al., Economic Incentive Policies Under Uncertainty: The Case of Vehicle Emission Fees (Resources for the Future Discussion Paper No. 96-32, 1996).

n159. See, e.g., Enterprise for the Env't, The Environmental Protection System in Transition: Toward a More Desirable Future (1998); Thinking Ecologically: The Next Generation of Environmental Policy (Marian R. Chertow & Daniel C. Esty eds., 1997).

n160. Rena I. Steinzor, Reinventing Environmental Regulation: Back to the Past by Way of the Future, 28 ELR News & Analysis 10361, 10362 (1998). See also Davies & Mazurek, *supra* note 18, at 15 (arguing that the very distinction between command-and-control and "incentive-based" approaches to regulation is misguided).

n161. It is worth noting that when the 104th Congress attempted a radical revolution in environmental regulation, it was left "licking its wounds." See Walter R. Burkley, Environmental Reform in an Era of Political Discontent, 49 Vand. L. Rev. 677, 678 (1996).

n162. See, e.g., A. Myrick Freeman III, Water Pollution Policy, in *Public Policies for Environmental Protection* 97, 125-26 (Paul R. Portney ed., 1990) (asserting that in 1985 the annual estimated costs of the Clean Water Act ranged between \$ 25 and \$ 30 billion while its "most likely" estimate of benefits was between \$ 5.7 and \$ 27.7 billion).

n163. Moreover, it is presumptuous to assume that efficiency is the lone or predominant goal of environmental legislation (whether or not it should be).

n164. Robert N. Stavins, Transaction Costs and the Performance of Markets for Pollution Control 29 (Resources for the Future Discussion Paper No. QE93-16, 1993).

n165. See generally Office of Technology Assessment, *supra* note 38.