EXTERNALITY PRICING

by

Angie L. Morris

Thesis

submitted in partial fulfilment of the

requirements for the Degree of

Bachelor of Arts with

Honours in Economics

Acadia University

April, 1999

This thesis by Angie L. Morris

is accepted in its present form by the

Department of Economics

as satisfying the thesis requirements for the degree of

Bachelor of Arts with Honours

Approved by the Thesis Supervisor

CFader Apr 19/99

Christina Fader Date

Approved by the Head of the Department

19th April '99

Peter G. C. Townley Date

Approved by the Honours Committee

21 April 1999

Date

I, Angie L. Morris, hereby grant permission to the Head Librarian at Acadia University to provide copies of the thesis, on request, on a non-profit basis.

Angie Morris

Signature of Authour

Signature of Supervisor

April 19/99

Date

ACKNOWLEDGMENT

I would like to thank Professor Townley and Professor Fader for all their time and effort in helping me complete this thesis, your hard work was greatly appreciated. I would also like to acknowledge the wonderful support received from my all friends, especially Paxton. Your faith in me has helped me more than you will ever know.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This thesis investigates the applicability of externality pricing to air pollution and noise pollution problems in passenger transportation. Potential and actual schemes are evaluated based on criteria of allocative efficiency, dynamic efficiency, informational requirements and political acceptability. Discussion focuses on why legislators favour direct regulation whereas economists deem externality pricing and other incentive schemes superior. Theoretically, externality pricing has an informational advantage over direct regulation. However, as real-world complexity is added to the analysis, doubt is cast on this alleged superiority.

However, direct regulation has not resulted in compliance. With externality pricing, there is no incentive to delay, it is cost effective, monitoring and enforcement costs are similar to direct control, and there is an incentive to innovate.

The current regulatory approach to automobile pollution and noise pollution from jet aircraft is flawed. Stringent standards for new cars and planes prolong the life of older, dirtier models by reducing the incentive to scrap them. The history of regulation has been one of delays and postponements. Cost effectiveness is also reduced due to the lack of flexibility in abatement techniques. A charge varying with the emissions of a particular pollutant per mile is suggested to decrease pollution from automobiles. For airport noise, a Pigouvian tax is recommended. These externality pricing schemes provide incentives for technological change, are flexible, enhance cost effectiveness, create no incentive to delay, and provide an incentive to maintain pollution control equipment.

CHAPTER 1

Introduction

This thesis reviews the pros and cons of externality pricing as it relates to the passenger transportation sector. Its focus is on approaches to control air pollution from automobiles and noise pollution from airplanes. Chapter 2 is a comprehensive survey of the literature pertaining to externality pricing and its proxies. Chapter 3 investigates proposed and actual uses of externality pricing, and it provides an analysis of second-best prices and other economic incentive schemes that have been popularized in the literature. In the environmental economics literature, externality prices are generally referred to as "emission fees" or "effluent charges." The latter term will be used extensively throughout this thesis.

The purpose of externality pricing is to correct resource misallocation or market failures resulting from externalities. As Baumol and Oates (1988:17) point out, "an externality is present whenever some individual's (say A) utility or production relationships include real (that is, non-monetary) variables, whose real values are chosen by others (persons, corporations, governments) without particular attention to the effects on A's welfare."

Examples of an externality occur when:

- A person drives a car to work in rush-hour traffic thus imposing a time cost on other drivers on the road;
- A jet aircraft takes off from Dorval Airport in the evening, waking residents who live near the airport; and,

- A thermal power plant emits sulphur dioxide from its smokestack, which injures vegetation and lakes downwind from the plant.

There are various categories of externalities discussed in economics. The first distinction is between pecuniary and technological externalities: a pecuniary externality arises when one agent's action causes prices to change, thus affecting the welfare of others. However, since there is no direct effect on real variables, this does not really create a misallocation (Baumol and Oates, 1988). In this thesis we are concerned only with technological externalities. Technological externalities can also be divided between external diseconomies and external economies. In the former case the agent imposes a cost on others, whereas in the latter, a benefit is imposed. All of the examples discussed in this thesis are external diseconomies.

These externalities or, more precisely, external diseconomies involve actions by agents that impose costs on others. Markets provide no incentive for agents to take these costs into account. Thus, as Baumol and Oates (1998: 17-18) point out, for this externality to be considered a misallocation it is also necessary that "… the decision maker, whose activity affects others' utility levels, does not receive (pay) in compensation for his activity an amount equal in value to the resulting benefits (or costs) to others."

Economists refer to such misallocations as market failures, since agents undertake actions (such as reducing the availability of clean air or peace and quiet) which use up scarce resources without incorporating the costs of such actions into their decisions. An economic solution to such problems involves setting externality prices that internalize these external costs. Of course, if the market failure involves an external economy, the solution would involve a per unit subsidy to the externality-generating activity.

Chapters 2 and 3 explore the theoretical strengths and weaknesses of externality pricing including a discussion of issues such as:

- Why a large segment of public policy-makers favour direct regulation of externality problems rather than pricing schemes; and,
- Why economists feel that externality pricing, or at least some form of economic incentive, is superior to direct controls.

Chapter 4 discusses the possible role of externality pricing in alleviating transportation air and noise pollution problems. Chapter 5 concludes the thesis with a summary of the findings with respect to the application of externality pricing.

CHAPTER 2

Externality Pricing

2.1 Theoretical Justification of Externality Pricing

The source of externality problems is often found in poorly defined property rights. This can be demonstrated with a simple example of an environmental problem. This example, drawn from Baumol and Oates (1971), also provides a theoretical basis for an effluent charge or externality price resulting from the failure of the market to place a price on environmental services.

The environment is an asset that yields waste-assimilative services to users; for example pulp and paper mills, municipal sewage treatment plants, smelters, etc. Problems arise to the extent that the asset is scarce. More waste emissions by firms means less environmental quality and hence less recreational and other services available to other users. The failure of the market to reflect the opportunity cost of these damages in a price for these waste-assimilative services induces their overuse by polluters. When making their production decisions it would be socially optimal if firms internalized the damages that result from their pollution emissions; otherwise they underestimate the costs of production and over-use. A charge per unit of pollution equal to the marginal social damage of pollution would solve the environmental problem. This is the basis for effluent charges or externality prices.

The ownership, or property right, of environmental assets is sometimes the source of debate. If the polluter is forced to pay for his or her use of this asset, then implicitly the property right is vested in the hands of those who suffer from pollution damages.

However, as Coase (1960) points out, in a limited market where negotiation is feasible, an optimal allocation results whether ownership of the asset is vested in the hands of polluters or those suffering from the pollution. That is, it is enough that some party owns the property right; it does not matter which, the polluter or pollutee. The outcome of negotiations will, in either case, be optimal. Of course, the ownership of the resource will affect the distribution of income.

In a large market where negotiation is not feasible, ownership of the resource is usually vested with some level of government. The government then must take action to induce a change in behaviour by the polluter. This action can involve effluent charges, regulations, subsidies or transferable discharge permits. The design of such schemes has definite distributional consequences, some of which are discussed in Chapter 4.

Assume there are two dischargers of the same pollutant which cause damage at a single receptor point. e_i is the total emission per unit of time from source i. In an uncontrollable state, source i would emit $Z_{i.}$ If this polluter emits less than Z_i it is abating pollution. Abatement at source i (A_i) is defined as:

$$A_i = Z_i - e_i \qquad i = 1,2 \qquad (1)$$

Each source finds it costly to reduce emissions below Z_i. Thus in the absence of some sort of external pressure or regulation, neither will choose to abate. Firms maximize profits and, as long as the environment has a zero price, the firm will choose not to limit its emissions. It will voluntarily abate only if emissions have some market value. The cost of abatement is defined as:

$$TC_i^A = C^i(A_i) = C^i(Z_i - e_i) \qquad \text{where } dC^i/dA_i > 0 \text{ and } d^2C^i/dA_i >= 0 \ (2)$$

Assume the pollution is from two sources, 1 and 2. The damage, TD suffered at the receptor, is defined as:

$$TD = f(e_1+e_2) = f(e) \qquad \text{where } df/de > 0 \text{ and } d^2f/de_2 >= 0 \qquad (3)$$

The regulatory agency's goal in this situation is to minimize the sum of the damage and abatement costs, i.e.,

$$\min f(e_1+e_2) + C^1(Z_1-e_1) + C^2(Z_2-e_2). \qquad (4)$$

The solution to this problem yields the following results:

$$df/de = dC^1/dA^1 = dC^2/dA^2 = c, \qquad (5)$$

where c is the constant marginal damage of pollution emissions. A graphic representation of this solution is provided in Figure 1, diagrams (a) and (b). The optimal externality price is shown to be equal to c, the marginal damage of emissions. This will result in the pollution sources choosing to emit e_1* and e_2*, thus abating Z_1-e_1* and Z_2-e_2* respectively. Pollution source 1 will pay ce_1* for the emissions that continue, equal to the total damages of e_1* emissions. Overall damage is $c(e_1*+e_2*)$ which is equal to the total payment by the two polluters. As a result, polluters are induced to take the damages they impose into account in their production decisions.

Concentrating on source 1 it is easy to see why abatement does not exceed Z_1-e_1*. Abatement beyond this point would involve a marginal cost of abatement larger than both the damages created by additional emissions and the externality price, c. If the authority knows the marginal damages of emissions, and if they are constant as has been assumed to this point, it need only set a charge c. The result will be optimal as the firms will automatically adjust their emissions to e_1* and e_2*. The authority needs no knowledge of abatement costs. Obviously, this result generalizes to the case of n polluters.

An alternative device, which is certainly more prevalent in North America, is the effluent standard. Optimality in the case just examined would involve setting an effluent standard of e_1* per unit of time for pollution source 1 and e_2* per unit of time for pollution source 2. The determination of these standards would require knowledge of not only the level of marginal damage, but also the marginal cost functions for all polluters. Thus there is an obvious informational advantage in the externality price scheme over the effluent standard.

However, the apparent advantage is neutralized to some degree when more realistic assumptions are introduced. These assumptions are discussed fully below, and we demonstrate that as the model becomes more realistic, an externality price may not be the optimal solution.

2.2 Nonlinear Demand Functions

To this point, the damage function has been assumed to be linear. This yields a constant marginal damage function and rules out, for example, threshold effects of pollutants. However, there is no reason to expect that damage functions will be linear. Indeed, the ultimate shape of a pollutant's damage function depends on various parameters.

One advantage of externality prices above is at least partially neutralized when the damage function is not linear. Such a situation is depicted in Figure 1(c). The downward-sloping kinked curve is the marginal abatement cost function. The curve labeled X is the new marginal damage of emissions function. The optimal level of abatement is $e^* = e_1^* + e_2^*$, and the optimal externality price is still c. Optimality now requires that:

$$df/de(e^*) = dC^1/dA_1(A_1^*) = dC^2/dA_2(A_2^*) \qquad (5')$$

Given that the authority knows the function df/de, it must first determine e* before setting the optimal externality price, c. The problem is that it is no longer true that the optimal charge equals marginal damage. The optimal price is now equal to the marginal damage at the optimal level of emissions (e*). The determination of e* would require knowledge of all marginal costs and marginal damages. The information advantages of externality pricing disappear.

2.3 Spatially Differentiated Damages

The previous sections have presented models in which a single externality price for a given pollutant is optimal. With a slight extension of the model it can be shown that there are likely many real-world situations for which this will not hold. This extension involves the assumption that the location of the polluter is relevant to the damage created by its emissions of a given pollutant. For example, polluters located downwind (or downstream) from a receptor will, on average, have no impact on the air quality (or water quality) and, hence, pollution damages at the receptor point. Obviously, the same is not true of an identical polluter located upwind (or upstream) from the receptor.

The relevance of this point can be demonstrated with the following model of a hypothetical airshed (Benford, 1998). Assume a region can be divided into n areas of homogeneous air quality or receptors with m polluters located throughout. Pollution damage, in each area (n), is a function of air quality, Q_i. Thus,

$D_i = D_i(Q_i) \qquad i = 1,2 \ldots n.$

The total regional damages are thus:

$D = \sum D_{i,}$ and

the cost of abatement to society is

$C = \sum C^j(A_i).$

The air quality at receptor i is:

$Q_j = Q_j(e_1, e_2, \ldots e_m),$

where e_j is emissions from source j.

Minimizing the costs of pollution implies:

$\text{Min } D + C = \sum D_i(Q_j(e_j, \ldots e_n)) + \sum C^j(e_j)$. Solving,

$$\sum \partial D_i/\partial Q_j \text{ x } \partial Q_j/\partial e_j = -\partial C^j/\partial e_j \qquad j = 1, 2, \ldots m. \qquad (5'')$$

This yields a system of n equations with m unknowns. If the damage function is linear in quality, then $\partial D_i/\partial Q_j = \alpha_i$. Thus optimality requires that

$$\sum \alpha_i \, \partial Q_j/\partial e_j = -\partial C^j/\partial e_j = c_j, \qquad (5''')$$

where c_j is the jth source's marginal cost of abatement.

For most types of polluters there is no reason to expect that a unit of pollution from all j sources will affect air quality in region i in the same manner. Thus $\partial Q_j/\partial e_j$ will vary according to the location of the polluter. This means that each polluter must now be assigned a different externality price.

The authority can still set the optimal charge provided it knows the damage function and the impact of discharges on air quality. Thus the authority, again, needs no information regarding the marginal costs of abatement. While the externality price (c_j)

must vary across sources, the authority retains the informational advantages originally attributed to it.

Once again, it should be clear that this advantage only occurs if the damage function is linear. If it is assumed that the damage function is not linear then equation (5''') becomes,

$$\sum \partial D_i/\partial Q_j\,(Q_j)\,\alpha_{ij} = -\partial C^j/\partial e_j \quad j = 1, \ldots m.$$

Since $Q_j = Q_j\,(e_1, e_2, \ldots e_m)$, the optimal charge is no longer independent of the optimal discharge level. Therefore, the above n equations must be solved simultaneously, and this requires knowledge of abatement costs as well as damages.

It is unrealistic to assume the damage function will always be linear, or that the authorities can easily generate a damage or marginal damage function (Dales, 1968). As a result, many economists have abandoned the idea of an optimal externality price (Sims, 1992).

2.4 Uncertainty of Marginal Damages and Abatement Costs

While the analysis to this point suggests that externality problems will not easily be solved by pricing policy, it has provided no insight into the popularity of the direct regulation (or command-and-control) approach that dominates much of environmental regulation. Uncertainty as to the extent of damages and costs on the part of regulatory authorities provides evidence that standards may dominate charges as the optimal solution.

A simple model based on the work of Adar and Griffin (1976) demonstrates such situations. To simplify the analysis, assume that the airshed in the model is perfectly mixed so that the location of the polluting firm and receptor of the pollution is irrelevant. Also, assume that the marginal abatement cost and marginal damage functions are linear. The analysis generally compares the relative welfare losses imposed on society by an externality price and a quantity-based regulation when the environmental authority is uncertain about marginal damages or marginal abatement costs.

Figure 2(a) shows a situation where the authorities have underestimated the true marginal damages of emissions (MD_e^T). Under a standard scheme they allow emissions of e, which is greater than the optimal level e*. The extra emissions increase damages equal to the area e*ACe, which is partially offset by a gain to polluters in terms of reduced abatement costs equal to the area e*ABe. The social loss from the standard scheme is given by area ABC. With the pricing scheme, the set charge (EC) is less than the optimal externality price, EC*. This leads to emissions of e rather than e* and a social loss equal to that under the standard. Therefore, uncertainty with respect to the marginal damage function advantages neither scheme.

In the case of uncertainty with respect to marginal abatement costs, this symmetry no longer holds. Assume, as in diagram (b) of Figure 2, that the true marginal cost of abatement (MC_A^T) is underestimated. In a standard scheme, emissions of e would be allowed, which is less than the optimal level e*. This will reduce damages by eACe* but will increase abatement costs by the amount eBCe*. The net social loss from the standard scheme is, thus, ABC.

Under a pricing scheme, the authorities would set a charge of EC, which is less than the optimal externality price of EC*. This would result in e' emissions, which is larger than e*. This would increase pollution damages by e*CDe' and reduce abatement costs by e*CEe'. The net social loss from the pricing scheme is, thus, CDE.

Adar and Griffin (1976) show that:

$$WL_T - WL_q = -1/2\ (EC/e)\ (\Delta e)^2\ [1/\varepsilon_D + 1/\varepsilon_c]$$

Where WL_T is the welfare loss from the pricing scheme (area CDE in the previous example); WL_q is the welfare loss from the standard scheme (area ABC in the previous example); ε_D is the elasticity of the marginal damage function; ε_c is the elasticity of the marginal abatement function; and, $\Delta e = e' - e$.

Thus, the welfare loss from charges or standards will be equal if

- the damage and cost elasticities are equal in absolute value, or
- Δe is 0, i.e. $MC_A = MC_A{}^T$, the authority knows the true marginal cost of abatement.

Therefore, standards are preferable to charges when $WL_T - WL_q > 0$, which occurs if $|\varepsilon_D| < |\varepsilon_c|$. As the elasticity of the marginal damage function approaches zero, standards are preferable, whereas as the elasticity of marginal cost of abatement approaches zero, taxes are preferable. The rationale for this result is as follows:

- If the marginal damage function is inelastic (steep) even a slight error in emission levels will result in very large damages. With uncertainty about costs, the chances of such errors are greater with a pricing scheme.
- If the marginal damages are relatively elastic (flat), a charge will better approximate marginal damages. As has already been shown, with a linear damage function, the charge can lead to an optimal result independent of any knowledge of costs.

- If marginal costs are inelastic (steep), then an overly ambitious standard could result in excessive costs to abators. The charge places an upper limit on such costs.

The key characteristic in these two schemes is that charges set an upper limit on costs, whereas standards set an upper limit on discharges. Nevertheless, the introduction of uncertainty into the analysis suggests that the alleged superiority of externality pricing is questionable.

2.5 Market Imperfections

Implicit in the earlier analysis was the absence of other causes of market failures. If the polluting firm is a monopolist, an externality price set equal to the constant marginal damage of pollution will not yield an optimal result (Baumol and Oates, 1988). This result should not be too surprising to those versed in the theory of the second best. This theory basically states that, in the presence of multiple market failures (in this case two market failures: pollution and monopoly power), correcting one of the failures will not necessarily result in a Pareto improvement (welfare gain). There may be a trade-off between the reduced adverse effects of market power and welfare loss to society (Hagem, 1998).

This result is illustrated in Figure 3. The monopolist, subject to constant marginal cost (MPC), chooses to produce the profit-maximizing output level OQ_m, for which it charges a price of OP_m. Assume that the environmental authority decides to impose a charge on the firm for each unit of pollution it emits to the environment.

Note the important distinction that this charge is levied per unit of emission and not per unit of output. A tax on output induces a firm to abate by reducing output, and the firm has no incentive to install abatement equipment or to change operating procedures. Even if these were less costly ways to control pollution, a charge on output would never encourage a polluter to undertake these activities. On the other hand, a charge on emissions would induce the polluter to seek out a least-cost method of pollution reduction: reducing output, altering operating procedure, or installing abatement equipment.

As a result, the monopoly reduces its pollution emissions per unit of output, which in turn increases the marginal private cost of production. Since emissions per unit of output are reduced, the marginal social cost of output is lowered. If the charge is set equal to marginal damage, the externality is internalized, and the new marginal social cost and private costs must be equal; i.e. $MSC_t=MPC_t$. As a result output will fall to Q_t and price will rise to P_t.

This policy results in a cost saving to society in the form of reduced pollution damages equal to the area of FCEH. As well, the reduction in output from Q_m to Q_t results in a welfare loss of ABCD.

Notice that an optimal solution could be achieved by imposing an externality price on emissions equal to marginal damages and paying the firm a subsidy of GJ per unit of output. This would lead to output of OQ_o and a price per unit of output of OH. An externality price set equal to marginal damages at the optimal level of emissions is often referred to as a “Pigouvian tax” after A. C. Pigou, who is often given credit for first suggesting this policy (Fullerton, 1997). Whether the Pigouvian tax will lead to an improvement in welfare depends on the relative sizes of the areas FCEH and ABCD. Oates and Strassman (1984) suggest that, from available parameter values, gains from environmental improvement (area FCEH) far exceed losses from reduced output (ABCD).

Another concern related to market structure is the reaction of firms to an optimal charge. The polluter, through appropriate actions, may be able to affect the charge. If the authority sets an optimal charge and then does not adjust it, there is no problem. However, as is pointed out by Baumol and Oates (1988), if the tax is set iteratively, by continuously setting the charge equal to "current" marginal damages, problems may arise. If the polluting firm realizes it can affect the charge by altering emissions, the result of an otherwise optimal tax could be above-optimal emissions. Baumol and Oates (1988) describe a situation in which a firm can benefit by increasing its emissions. By driving away those affected by pollution, the marginal damage of emissions and, hence the tax, is reduced.

2.6 Non-convexities

Baumol and Oates (1988) show that a sufficiently strong externality that interferes with the production of some other good could give rise to a non-convexity in the social production set. In such a case, the second-order conditions for a social optimum are violated. If this occurs, then society may be left with the difficult problem of choosing among a number of local optima.

When second-order conditions are fulfilled and a competitive equilibrium (in the absence of market failure) is attained, the economy will achieve a Pareto optimal allocation of resources. At this allocation all producers and consumers will be in equilibrium and the value of total output will be maximized. This means that for given equilibrium prices and budget constraints, a competitive economy will always move to the highest point of tangency between the budget constraint and the production possibilities frontier. The concept of a potential Pareto improvement is based on the ability of gainers from a policy change to more than compensate losers. Such a change would obviously increase the value of output.

A typical Pareto optimal solution is shown in Figure 4(a). In this diagram, RR' is the production possibilities curve, I is the community indifference curve, and BB' is the budget line. Equilibrium is attained at E. At this point, a Pareto optimal solution has been attained and the value of output has been maximized. Indeed, it is because these two results coincide and because a competitive economy maximizes the value of output that we can attribute normative significance to a competitive equilibrium.

Non-convexities, however, create difficulties. Consider the production possibilities curve in Figure 4(b). An interior point can no longer represent the position that the value of output is maximized. Indeed, there will be two local maxima, at R and R'. If the price of X is high relative to Y, the highest value of output will be attained at R' and *vice versa* for a relatively high value of Y. In this case, E does not correspond to a maximum.

Therefore, we can no longer be certain that a Pigouvian tax, or optimal externality price designed to maximize the value of output, will lead the economy, to a Pareto optimal outcome. As is pointed out in Baumol and Oates (1988), this tax might not even lead the economy in the direction of the optimum.

Burrows (1980) provides a simple explanation of this phenomenon. While it is generally expected that the marginal damage of pollution will rise (or be constant throughout), this may not be the case. For example, if pollution drives the receptor from a region because of damages suffered, thereafter the additional damages of increased pollution would be zero. Thus, if there is diminishing marginal impact of pollution, the marginal damages of pollution may eventually diminish. This could lead to a solution like that depicted in Figure 4(c).

Here there are two local optima, E_1 and E_2. Assume the economy is initially at $e = Z$ and that the authority chooses an iterative pricing approach. The authority first calculates the current emissions, Z, and the current marginal damages $MD_e(Z)$. It then sets a tax equal to those damages, t_1. Polluters would react by reducing emissions until $t_1 = MC_A$, which occurs at e_1. The authority would then adjust the tax to $MD_e(e_1)$ and the process would continue. It would eventually stop at E_2, one of the global optima. As can be seen in Figure 4(c), if area A exceeds area B, the global maximum could occur at $e = 0$. Therefore, when the marginal impact of pollution diminishes after some point, the iterative procedure suggested in Baumol (1972) may lead the economy to the wrong optimum. Of course, if the authority had complete information on MD_e and MC_A, it could set an optimal externality price. If area A is larger that area B, the optimal tax is t_3; but, if B>A, then it is t_2.

2.7 Summary

There are a number of reasons to doubt the ability of a regulatory agency to use theoretically optimal externality pricing. These include nonlinear damage functions, spatially differentiated damages, uncertainty concerning marginal damage and abatement cost curves, market power, and nonconvexities. The most serious of all of these is the latter because it implies that we can not even be sure of the correct direction in which to modify an externality. This problem, however, probably affects all control policies equally.

Another key point is that with current levels of knowledge we are unable (for most pollution problems) to say much about the location or level of the marginal damage of pollution function (Baumol and Oates, 1988). This is the Achilles heel of the maximizing approach to environmental policy. As Baumol and Oates (1988: 161) point out, an optimal externality price requires knowledge not of current marginal damage but rather of marginal damage at the optimal emission level (see Figure 1(c)). "If there is little hope of estimating the damage that is currently generated, how much less likely is it that we can evaluate the damage that would occur in an optimal world that we have never experienced or even described in quantitative terms."

As a result, much of the current literature on externality pricing has lowered its sights somewhat by adopting a "satificing approach." First discussed by Baumol and Oates (1971), this approach uses standards set by the government agency as targets and adopts the most cost-effective policy available to achieve these goals. It is based on an implicit separability of decisions on the optimal policy goal and how to achieve it. As well, it requires a belief that the true comparative advantage of economists is in the determination of the latter decision.

The "externality price" has been resurrected by some economists as the policy of choice to achieve the goals of the "satisficing approach." Chapter 3 of this thesis considers this approach and presents arguments for and against the use of second-best externality prices to achieve environmental goals.

CHAPTER 3

The "Satisficing" Approach to Externality Pricing

3.1 Introduction

Much of the current environmental economics literature incorporates two main themes:

- direct regulation versus economic incentives, and
- the choice of economic incentives versus transferable discharge permits (TDP).

This chapter discusses the advantages and disadvantages of economic incentives (primarily second-best externality prices or effluent charges). The case made for or against these incentives is relative rather than absolute since, ultimately, we are not asking which policy will lead to a Pareto optimal solution, but rather which policy is better than the others. The idea is to determine which policy will achieve a given standard (that may or may not be optimal) in the most desirable way. The evaluation of these policies is based on the criteria of economic efficiency, dynamic efficiency, informational requirements, and political acceptability. Ultimately, no policy will be superior on all counts, and some situations call for a mixture of policies. Nevertheless, there appears to be significant evidence supporting some form of economic incentive to supplement, if not replace, direct regulation in certain situations.

To place the analysis of economic incentive schemes in a proper light, it is necessary first to look at the form of environmental regulation currently used almost exclusively throughout North America, direct regulation.

3.2 The Direct Regulation Approach

Jurisdictions throughout North America are committed to a direct regulation framework for controlling environmental problems. Ambient and effluent standards provide framework objectives which are, at least in theory, enforced by the threat of fines and/or imprisonment. Ambient standards define allowable concentrations of pollutants in a water body or airshed (Horan, 1998). Effluent standards define the allowable discharge of a pollutant from a particular pollution source. This framework often includes some form of financial assistance that is intended to help the polluter comply with environmental objectives and regulations. The most popular types of financial assistance in North America include accelerated depreciation allowances on capital expenditures for pollution control equipment, the refund of sales taxes on purchases of such equipment, and direct subsidies and loans for the purchase of pollution control equipment.

The approach to environmental regulation used in Ontario and some other jurisdictions has been described as one of “symbolic actions” (Dewees, 1980). Tough standards that sometimes appear to ignore abatement costs are established. But the apparent rigidity of these standards is only symbolic. When setting objectives and deadlines, and enforcing compliance, exceptions are made through negotiation. Agreements that may be less restrictive than that stated in law are made. Implementation deadlines are often deferred. Enforcement through court action and fines are viewed only as a last resort.

One of the chief criticisms of the direct regulation framework is that it has not been successful in persuading polluters to comply with pollution abatement schedules developed by environmental authorities. It has been argued that this method of regulation, instead of providing an incentive to abate, has provided an incentive for polluters to delay expenditure on pollution abatement (Roberts, 1970). In deciding whether to comply with current environmental requirements, a firm will weigh the cost of non-compliance or delay against the "rewards:" the cost savings because research and development may ultimately produce cheaper methods of abatement, more generous financial assistance from governments in the future, and the use of scarce capital that would have gone to purchase pollution control equipment for profit-making investments. In addition, non-complying firms save on operating and maintenance costs that would have been incurred had the appropriate abatement equipment been in place.

The costs of non-compliance, or delay, are the adverse public reaction and fines that result from prosecution. Given the technical complexity of many modern production processes, however, it is easy to give the appearance of co-operation by undertaking successive engineering and cost studies. This also helps highlight technical difficulties that can cause further delay and help to avoid prosecution. In essence, the direct regulation approach provides significant rewards for non-compliance and provides insignificant costs for delay.

Therefore, if a firm does not comply with environmental standards, it runs a rather small risk of prosecution or fine. It is unlikely that the magnitude of a fine will exceed the cost savings from delaying compliance. In addition, a firm which exceeds a pollution standard must first be caught which, if it is one of many firms, is difficult. Even if it is caught, it can probably negotiate the fine if, as in most jurisdictions with finite budgets for environmental litigation, the authority is seeking voluntary compliance. Moreover, where abatement options are costly and uncertain, the firm can make a good case regarding the unreasonableness and unfeasibility of current requirements. Any delay, whether this delay is the result of litigation or bargaining with the environmental agency, has clear and substantial benefits for the polluting firm (Amacher, 1998).

By reducing the cost of abatement, financial assistance tends to reduce the reward to polluters from delaying compliance. But as long as abatement costs remain, a substantial net loss item for the firm (as is likely even with significant tax incentive and subsidy schemes) it is unlikely that financial assistance will persuade firms to comply.

There is ample evidence in the literature of this tendency to delay compliance or only to appear to comply. A case in point is INCO. A Ministerial Order issued in 1970 required a staggered reduction of INCO's sulphur dioxide (SO_2) emissions at Copper Cliff to the following levels (Joskow, 1998):

Table 1:

1 July 1970	5200 tons per day
31 December 1974	4400 tons per day
31 December 1976	3600 tons per day
31 December 1978	750 tons per day

Originally INCO had intended to use a hydrometallurgical process to remove about 40% of the sulphur from the total feed to the smelter (Felske, 1981). In the end, INCO refused to implement the process. In 1973, INCO requested a two-year extension for the 1976 limitation, and the elimination of further requirements. In the requested amendment, INCO indicated that, "…the hydometallurgical option had under research scrutiny proven to be technically possible but not financially viable" (Felske, 1981: 141). This amendment was denied. In 1975, INCO proposed to reduce emissions through smaller modifications and the production of sulfuric acid. Once again, INCO backed out of this commitment for financial reasons. Between 1973 and 1978, INCO conducted a voluntary emission-reduction program based on local meteorological conditions, dispersion modelling, and smelter process adjustments. The objective was to control ground-level concentrations of SO_2; in July 1978, the Ontario Ministry of the Environment issued a control order extending an emission level of 3,600 tons per day, i.e. the 1976 limitations to mid-1982.

In 1980, INCO proposed an improved flotation method for increasing pyrrhotite rejection, to be implemented within two years. In April of the same year, the Ministry announced a draft control order calling for an immediate limit of emissions to 2,500 tons per day with a limit of 1,950 tons per day by the end of 1982. These limits were subsequently incorporated in a regulation under the *Environmental Protection Act.*

Felske (1981) suggests that INCO has avoided the constraints imposed in various control orders by using technical and financial arguments. The company promised to adopt technically advanced methods of abatement but, in the end, refused to adopt them for financial reasons. The catch is that it is never financially viable to adopt an investment that does not generate revenue.

This opportunity for delay also seems to be behind the lack of progress in pollution control by pulp and paper mills in Ontario. Victor and Burrell (1981) found that while there has been environmental improvement at the industry level, such improvement was slower than expected and did not reflect a uniform pattern among all mills. Ineffective enforcement by the Ministry is dramatically exemplified by the record of prosecutions and fines brought against mills, and the history of control order amendments and postponements until 1977 in Ontario.

There were 17 separate, environmentally related prosecutions of pulp and paper mills between 1968 and 1977. When fines were imposed they were generally $2,000 or less (Victor and Burrell, 1981), an amount unlikely to induce timely compliance among recalcitrant polluters. Because of the limited success of the regulatory program in use since 1965, the Ontario Ministry put all non-complying mills on control orders in 1977. However, since then there has been an abundance of control order amendments and postponements in response to requests by the mills (Victor and Burrell, 1981). This evidence is entirely consistent with Roberts' (1970) suggestion that the direct regulation framework provides an incentive for industries to delay expenditures on pollution abatement.

As further evidence of the failure of the direct regulation framework in Ontario, Victor and Burrel (1981: 128) note the following:

- Between 1973 and 1976, the number of mills in Ontario in compliance with federal toxicity requirements rose from one to nine and remained unchanged to 1978. This number represents only one-third of the pulp and paper mills in Ontario.
- In 1965, the Ontario Water Resources Commission sent a directive to all pulp and paper mills in Ontario requiring that the level of suspended solids in waste emissions be reduced to 50 mg/L by December 31, 1966. By 1978, the average discharge from the industry in Ontario was nearly 110 mg/L, nearly double the level required by 1966.

When regulatory objectives that are more than 15 years old have still not been met, it seems reasonable to speculate that changes are in order. The history of efforts to control automobile pollution in the U.S., is one of delay. Indeed, in 1969, the US Justice Department brought charges against auto manufacturers for collusion in delaying the development of pollution equipment.

The first legislated national control standards in the US were passed in the 1965 *Clean Air Act*. This placed restrictions on hydrocarbon (HC) and carbon monoxide (CO) emissions, which were to be met by 1968. The first requirement for mandatory exhaust control devices was passed in California, and required installation by the 1966 model year. Manufacturers vigorously opposed this.

In 1970 the Clean Air Act Amendments required that all new car emissions be reduced 90 percent below uncontrolled levels for HC and CO by 1975 and for nitrogen oxide (NO_2) by 1976. The auto manufactures requested an extension of these standards by one year. They eventually won this extension in a court case on grounds of technical infeasibility. Congress granted a further extension of one year in 1974 as the result of the OPEC oil embargo. The original 1975 standards had not been met by the early 1980s.

In addition to problems similar to those outlined above with respect to pulp and paper and INCO, there is an additional peculiarity in the history of auto pollution control: the sanctions were so brutal that enforcement was nearly impossible. If an engine family failed its certification test, the relevant vehicle class could not be sold. Given the importance of the auto industry to the economy, along with tough foreign competition, such a sanction was unlikely to be stringently imposed on manufacturers. The regulatory authority was pressed to allow delays, set weaker standards and reduce certification requirements. Eventually, deadlines became so flexible that no manufacturer could fail to achieve them.

While the control order amendments and postponements mentioned above might have legitimately resulted from technical difficulties, this only suggests another weakness in the direct regulation framework, in that it does not provide an incentive for innovation or advancement. Research and development could overcome the technical difficulties that have necessitated these amendments and postponements. Unfortunately, it is not in the interest of polluters to overcome these difficulties or to expend resources in attempting to do so. In addition, any advancement from such research might be imposed on a firm when control orders are renewed. This is not likely to be desirable from a firm's point of view since it would increase the firm's capital outlay with no corresponding increase in profits. Thus, there is little incentive for polluting firms to conduct serious research into pollution abatement techniques under the direct regulation approach.

It is recognized in the literature that under the direct regulation approach there is a tendency to set stricter quality standards for new sources than for existing sources. This makes economic sense when new plants can be built to take advantage of economies of scale or to install less pollution-intensive processes. This differentiated regulation, however, provides an incentive for firms to continue to operate obsolete facilities rather than replace them with new facilities. In this way firms can delay compliance with the more stringent environmental standards that only apply to new facilities. Such a policy can, over time, have an adverse impact on productivity and, in the short run, could actually increase pollution emissions.

Gruenspecht (1982) investigated the impact of this grandfathering in the auto industry. Raising the price of new automobiles through stricter controls prolongs the life of older, more emission-intensive automobiles. The possible short-run effect is increased pollution emissions. Gruenspecht (1982: 330) concludes that while "...tighter new source standards are ultimately reflected in lower aggregate emissions, their impact on investment plans can result in undesirable short-run outcomes. Clearly, other regulatory tools are needed as substitutes for, or supplements to, the differentially stringent regulation of new sources. Policies designed to promote the retirement of old capital are particularly attractive."

Within the direct regulation framework, one of the major sources of financial assistance available to firms is in the form of tax provisions intended to encourage expenditures on pollution abatement equipment. This type of financial assistance may reduce efficiency: because the tax concessions can be applied only to capital expenditures, they encourage a firm to adopt abatement techniques which need a lot of equipment, even if these techniques are not economical for reducing pollution. An example of the perverse incentive created by such tax provisions in presented in Roberts (1970:153):

> "Suppose... a firm has a choice between two methods of abatement. One method involves purchasing a significant amount of land on which to construct treatment ponds. The other method is to buy a set of mechanical devices. Under the current tax laws, the investment in mechanical devices would be depreciable, while the investment in land would not. Thus, considering tax breaks, the mechanical approach might cost the firm less than the land-use approach, while the real cost to society, that is, the cost before taxes of the land purchases method, would have been cheaper."

These tax provisions may also influence abatement choices away from least-cost techniques that have high operating costs or which involve process changes if, as is often the case, the tax break applies only to facilities and equipment designed specifically for pollution abatement.

Another criticism of financial assistance based on tax concessions is that tax provisions are only of use to profitable firms, providing more to firms that pay higher corporate income taxes. Therefore, these programs provide the least support to those firms that require it most.

3.3 The Second-Best Externality Price

Despite the problems of externality pricing discussed in this chapter, many economists still argue that they compare favourably with the direct-regulation enforcement framework (Anderson *et al.*, 1977; Baumol and Oates, 1988; and Dewees, 1991). A workable effluent charge is designed to achieve a predetermined environmental standard. A uniform charge per unit (i.e. pound, ton, etc.) of a particular type of pollutant (for example, SO_2) is set for all major polluters to achieve some overall standard. Cost-minimizing firms will abate pollution in response to such a charge as long as the marginal cost of abatement is less than the effluent charge. In essence, the individual firm abates pollution until the marginal cost of abatement equals the charge.

A simple example can illustrate this idea. If the uniform charge were $5 and the extra or "marginal" cost to the firm, at current levels of abatement, of abating one more unit of pollution were $2, a cost-minimizing firm would abate because it would be cheaper than paying the charge. Additional abatement would cost $2 per unit but would save the firm $5 in effluent charge payments, thus yielding a net gain to the firm of $3. Obviously, abatement will be expanded as long as the charge exceeds the incremental or "marginal" cost of abatement.

While a uniform charge is set for each point source, a different charge would likely apply to each pollutant included in this scheme. The overall standard must be determined by the environmental authority, and it should be stated as the amount of a particular pollutant that can be emitted into the environment over a certain period of time. For example, the overall standard might be such that all major SO_2 emitters in a jurisdiction be allowed to emit one million tons of SO_2 into the air per year. The "standard," however, would not be translated into a restriction on the emissions of any particular point source. The appropriate method of achieving this standard would be to set an effluent charge and to alter this charge during each time period until the overall standard was achieved. In this case, because the overall standard is set per annum, the charge would be adjusted each year if it were determined that aggregate emissions of SO_2 were not exactly one million tons.

Under, this scheme, the charge would have to be adjusted over time in order to compensate for inflation and growth (Fisher, 1981). Continuing inflation would mean a decline in the real value of the charge if its nominal value were fixed. This would result in emissions in excess of the desired level in particular years. Indexing the nominal charge to vary with the annual inflation rate would largely overcome the (possibly) costly necessity of annually altering the charge by administrative decree.

Growth of output over time and the resulting increase in the production of polluting by-products require increasingly stringent abatement if the overall standard is to be maintained (Magat, 1978). The incentive to increase levels of abatement may require increases in the real value of the charge. Thus the charge might have to be adjusted upwards by administrative decree. The signal for such an adjustment would be given when emissions from relevant sources, in aggregate, exceed (or fall short of) the desired standard. The charge would then be adjusted in order to achieve the overall standard.

Obviously, this system must be monitored, not to detect violations at individual sources but rather in order to determine the total emissions from each source per time period. This would likely require taking a number of random samples of emissions from each point source that would then be used to calculate the total emissions from that source during a particular time period.

This data would then serve two purposes:

- When aggregated for all relevant sources, it shows whether the overall standard is being met and, hence, whether the charge should be altered; and,
- It determines the payment by individual sources which can then be calculated as the charge, t, times the calculated emissions from the source.

Monitoring some pollutants, such as SO_2, at certain sources may be somewhat simpler than at other sources. A knowledge of the sulphur content of the fuels being burned, the quantity of fuels being burned, and the amount of sulphur being collected in abatement would yield adequate estimates of emissions. Unfortunately such techniques can not be applied to all pollutants or sources. At any rate, continuous monitoring is not a requirement of this scheme.

This variant of the effluent-charge scheme compares favourably with the direct regulation approach. Under the effluent charge there is no incentive to delay the installation of abatement equipment. While the failure to install equipment results in the same type of cost savings described earlier, it also results in larger effluent charges in this case. While there is no incentive for bargaining or delay of compliance once the charge has been set, there will likely be bargaining over whether this type of scheme should be imposed at all and what the initial level of the charge should be.

The effluent-charge scheme is a decentralized method of control. Once the charge is set, it is up to the firm to decide how to reduce pollution emissions. There are usually several possibilities: end-of-pipe treatment, process change, output reductions, input reductions, change of product mix, etc. One advantage of such an approach is that because it is the firm which chooses the appropriate methodology, it will obviously do so in the manner which will minimize the costs of achieving a given level of abatement. Under the direct regulation framework, in which a plant is sometimes ordered to adopt a particular abatement technology, a firm's choice of abatement technique is reduced. As a result, abatement costs at a source will likely be higher under direct regulation.

A criticism of economic incentives, particularly effluent charges, is that they provide a licence to pollute. Legislators and environmentalists often contend that when faced with a charge, firms will merely pay the charge and continue to pollute (Kelman, 1981). The empirical evidence, however, does not support this claim.

Much of this evidence can be found in studies of a prototype of the effluent charge called "sewer surcharges." In one study of poultry–processing plants located in various U.S. cities, Ethridge (1972) found that for every 1% increase in surcharge rates, Biochemical Oxygen Demand (BOD) discharges per 1,000 birds fell by 5%. Elliot and Seagraves (1972), in a study of the overall impacts of these sewer surcharges in the U.S., found that the industrial BOD emissions corresponded negatively to the level of surcharge. A 1% increase in the surcharge rate in a typical city was found to result in a 0.8% decline in industrial BOD emissions. Sims (1979) found considerable responsiveness to surcharge schemes by breweries in Canada. For example, a 1% increase in the surcharge rate on BOD caused a 0.563% decline in BOD emissions from one brewery. The evidence provided by these studies of responsiveness to economic incentives tends to refute "licence to pollute" arguments.

It has been argued that effluent charges have an advantage over direct regulation in cost effectiveness and informational requirements. It rests on a comparison of the cost effectiveness of effluent charges and effluent standards in achieving a reduction in the emissions of a particular pollutant. The effluent charge is adjusted until the required abatement is achieved. With the uniform standard, total abatement is divided equally among all sources. Provided that all sources do not have identical control cost functions, the costs of achieving a given level of abatement will always be minimized with the charge.

There are at least two problems with this argument:

- an effluent standard which is cost effective could obviously be designed; and,
- the cost effectiveness of these single-price schemes disappears when firm location and pollution dispersion become important as they undoubtedly are in the real world.

The first problem implies, correctly, that almost any environmental policy can be cost effective and, as a result, the relevant question involves the necessary informational requirements. The informational requirements for a cost-effective charge scheme are influenced by a second problem. If the goal of the program is to limit the size of total emissions at least cost, the authority might set a standard limiting total emissions (by weight) to a certain amount (S). Assuming only two polluters, the optimization problem would then be:

$$\text{Min } C_1(Z_1 - e_1) + C_2(Z_2 - e_2) - \lambda[S-e_1-e_2] \qquad (7)$$

where e_1 is the total emissions per unit of time from source i, and λ is the Langrangean multiplier. In an uncontrollable state, source 1 would emit Z_1. (Assume the same is true of source 2). If this polluter emits less than Z_1 it is abating pollution. As defined in Chapter 2, abatement at source 1 (A_1) is defined as:

$$A_1 = Z_1 - e_1, \text{ and} \qquad (1)$$

the cost of abatement is defined as:

$$TC_1^A = C^1(A_1) = C^1(Z_1 - e_1). \qquad (2)$$

The first order condition of equation (7) suggests that:

$$dC^1/dA_1 = dC^2/dA_2 = \lambda \qquad (8)$$

Thus, each polluting firm should abate until marginal cost of abatement is equal across all firms and the constraint $S = e_1 + e_2$ is met (See Figure 5). Since we know that profit maximizing firms will choose to abate until

$$dC^1/dA_1 = t$$

where t is the externality price, then it is clear that λ is the externality price which will achieve the aggregate standard at least cost (Sims, 1992). This pricing scheme has the advantage over an effluent standard scheme of requiring less information. λ could be determined with little or no knowledge of abatement costs through iteration. Assume the authority sets the initial charge t_o greater than the marginal cost of abatement. It would observe aggregate emissions $E_o < S$, indicating that a reduction of t is needed. If it sets a charge t_1 less than the marginal cost of abatement, it will observe aggregate emissions E_1

> S, indicating that an increase in t is needed. The process would also provide cost information to the authority. On the other hand, an effluent standard approach would require knowledge of all abatement costs in order to be cost effective.

Of course, the iterative procedure is not costless. If firms react to an initial charge by installing slow-depreciating capital equipment, the reaction to changes in charges may not result in a least-cost solution. Baumol and Oates (1988) suggest that advanced warning of the possibility of tax changes would allow polluters to build flexibility into their plant designs.

While this externality price is not, in general, Pareto optimal (unless S happens to be the optimal aggregate standard), it does guarantee the given reduction of aggregate emissions at least cost. This cost effectiveness appears to be the primary advantage of the externality approach.

However, despite the difficulties of estimation, it is the damage of pollution emissions that causes concern. Thus a standard more closely aligned with damages seems desirable. Ambient standards at a receptor point would seem better able to fulfill this requirement.

Assume there is a single receptor and that the target concentration of pollutant at the receptor is S_A. Also, assume that a unit of emissions from point 1 increases the concentration at the receptor by α_1 and from source 2 by α_2. Therefore, a cost-effective policy would:

$$\text{Min } C^1(Z_1 - e_1) + C^2(Z_2 - e_2)$$

Subject to: $\alpha_1 e_1 + \alpha_2 e_2 + B <= S_A$

where B is the background concentration of the particular pollutant (which is unrelated to emissions from either polluter [Sims, 1991]). It is assumed that B is constant and less than S_A.

The solution to this problem implies that:

$dC^1/dA_1 = \lambda\alpha_1$

$dC^2/dA_2 = \lambda\alpha_2$

Therefore, $(dC^2/dA_2)/(dC^1/dA_1) = \lambda\alpha_2/\lambda\alpha_1$

Even an iterative procedure could be used. The effluent charges would differ between the two sources depending on the constants α_1 and α_2 . However, the ratio of the two charges would be a constant equal to the ratio of the α's. Thus the authority could set a charge of t_1 on source 1 and $(\alpha_2/\alpha_1)\ t_1 = t_2$ on source 2. If the concentration of pollution were too high, t_1 would be increased. Since t_2 is defined in terms of t_1, it would follow suit. All that is required is that the authorities know α_1 and α_2.

3.4 Dynamic Efficiency

The previous section suggests that the cost-effectiveness of externality pricing may be suspect under certain circumstances. However, one of the strongest arguments for externality prices is that they are more inclined to induce technological change in abatement techniques than is direct regulation. It is thus more efficient in a dynamic sense. For example, Dewees (1980) argues that under a standard scheme, there is no incentive to develop a technology that achieves more abatement than is required by the standard. Effluent charges, however, provide a continuous incentive to abate. If so, then abatement costs will decline more quickly over time and an externality price, in the long run, may be more important than cost effectiveness.

Milliman and Prince (1989) present a more complete comparison of the dynamic efficiency of effluent charges and the direct regulation approach. As they point out, most of the analysis on technological change is firm specific. However, as Milliman and Prince point out, costs are reduced not only by these firm-specific innovations, but also by diffusion of innovation to other firms and an optimal industry response to these changes. They argue that the cost reductions brought about by these latter two changes likely dwarf those of the firm-specific gain. As well, any delay in these changes will reduce the overall gains from innovation.

Their comparison of alternative policies is based on a model presented in Figure 6. Assume that there are N competitive firms emitting homogeneous waste into a perfectly mixed environment. Initially, the optimal level of emissions is E*, which may be achieved with a charge of T* or an effluent standard of e* against each firm, where E* = Ne*. Assume that the firm in diagram (a) develops an abatement innovation that shifts the marginal cost of control from MC to MC'. This does not initially affect the industry marginal abatement cost (MC in diagram (c)) since the innovating firm is small relative to the market.

Before innovation, the pollution-related costs of the innovating firm include abatement costs, $e_m ae^*$ and tax payments, e^*OT^*a. As a result of the innovation, the firm in diagram (a) reduces its emissions to e' and finds that its pollution-related costs include abatement costs of $e_m fe'$ and tax payments of $e'OT^*f$. Thus the firm's gain from innovation under a charge scheme is $e_m fe$. Under a direct control scheme, emissions remain at e* and the gain to the firm is thus $e_m$ca. The incentive for the firm-specific innovation is obviously greater under the charge scheme.

Widespread diffusion of the innovation in the industry will eventually cause the MC curve of the (N-1) non-innovating firms to shift to MC', and the industry marginal cost of control thus shifts from MC to MC". It is assumed that the agency does not initially perceive the change and, thus, does not alter its policy. There is no further gain to the innovating firm under either of the schemes. Indeed, diffusion may threaten the innovator's gains through increased market competition.

There is certainly a gain to non-innovating firms. But, once again, the incentive to promote innovation (by other firms, given that diffusion is expected) is greater under the charge scheme. Under the charge scheme the non-innovative firms in diagram (b) save $e_m$fa, whereas under the direct controls each one saves $e_m$ca.

Finally, it is assumed that the authority adjusts aggregate allowed emissions to the optimal level of emissions E** and each firm's to e**, where E** = Ne**. Under the charge scheme, T* is lowered to T**. The industry gain from this optimal alteration in the charge is shown in diagram (c) as DT**T*F. The principal concern here is the industry gain, since it indicates the propensity for political action, (i.e. the propensity of the industry to demand an optimal reaction by the government).

With direct controls, optimal behaviour by the authorities results in aggregate emissions E** and a firm level of emissions of e**. This results in a loss of E*E**DC. Thus, under direct controls there is no particular reason to expect industry pressure for optimal adjustments (Sims, 1992).

The overall gain from innovation, diffusion and optimal policy adjustment can be summarized as:

a) under charges: $E_mFA + T^{**}T^{*}FD > 0$

b) under direct controls $E_mCA + E^{*}E^{**}DC >$ or < 0

This analysis suggests that there is not much of an incentive for innovation under direct regulation, especially if the government adjusts standards in an optimal manner to perceived declines in cost. Obviously, the externality price is much more likely to induce technological change. Indeed, if it is perceived that there are potentially substantial gains from the entire process, it is more likely that the initial innovation will take place.

Figure 6 can also be used to investigate the dynamic efficiency of second-best standards and charges. Assume that the authority sets the standard E* and changes the charge iteratively in order to maintain this level of emissions. With respect to the standard scheme, the authority sets an aggregate standard of E*, which translates into firm standards of e*. These are not adjusted. This second-best scheme would be adopted for reasons discussed earlier in this chapter, not the least of which might be that information on the marginal damage function is limited.

The earlier conclusions still hold regarding the relative cost savings under the two schemes (charges and direct controls) from firm-specific innovation and diffusion of the innovation. The third stage in the process is, however, altered. Since the authority does not alter E*, there is no loss to firms under the standard scheme. With the charge scheme, however, the authority will adjust the charge downward to T in order to retain aggregate emissions at E*. The industry gain from this adjustment is even greater than under the optimal adjustment analyzed earlier. It is TT*FC.

The overall gain from the innovation, diffusion and second-best policy adjustment rule can now be summarized as:

a) under charges: $E_mCA + TT^*AC > 0$

b) under direct controls: $E_mCA > 0$

Under the second-best policy rule there is a definite incentive for innovation under direct regulation, but it is certainly smaller than under the externality price scheme (Sims, 1992).

The incentive for innovation under direct regulation is probably even less than the above analysis suggests. First, the above models do not incorporate the differential regulation that characterizes most real-world direct regulation programs. Second, the setting of standards that are stricter for new polluters extends the life of old technology.

3.5 Enforcement and Monitoring

Most of the analysis carried out to this point assumes that monitoring and enforcement are costless and that firms voluntarily comply with environmental controls. However, monitoring and enforcement costs have definite impacts on the analysis of optimal externality prices and their relative desirability (Lee, 1984). Some claim that monitoring costs are a particular disadvantage to pricing schemes while others claim that charge schemes have enforcement advantages over direct controls (Russel, Harrington and Vaughn, 1986).

When individuals or firms are required to act against their self-interest, it seems unreasonable to expect voluntary compliance; hence penalties or sanctions are required.

However, since the authorities must first identify those sources not in compliance, monitoring is a necessary prerequisite to effective environmental control.

The nature of emissions and behaviour of polluters makes monitoring difficult. Since pollution sources are hard to identify after the fact, monitoring must take place at the source. As well, counter to common assumption, discharge sources do not have perfect control over emissions. Operating changes, human error, equipment failures, etc. all affect discharge. As a result, a polluter who installs the appropriate control equipment and operates it effectively may still be observed to be in violation some of the time (Russel, Harrington and Vaughan, 1986). On the other hand, some polluters may not comply because penalties and monitoring are ineffective. Distinguishing between the compliant polluter whose random emissions are observed in excess of the standard at a specific time and the non-compliant polluter is likely not perfect. Thus some innocent firms may be convicted of violating standards.

The variable nature of emissions when combined with imperfect monitoring equipment introduces some ambiguity to the notion of enforcement. This problem is compounded by uncertainties regarding the legality of entry into plants for the purpose of monitoring. It is often contended that for safety reasons the monitoring agency must announce intentions of a visit in advance, a requirement that seems likely to introduce some bias into the data collected.

Monitoring certainly creates problems for environmental programs, but why should these problems be more severe for charges than for standards? It is sometimes alleged that design or technological standards are easier to monitor, since instead of requiring a certain level of abatement or emissions, they require a certain type of equipment. Such an approach in the U.S. involves the observation of installation and testing of the required equipment (Russell, Harrington and Vaughan, 1986).

Indeed, this type of monitoring may offer few logistic or cost problems but, ultimately, it is ineffective. It provides no incentive for the polluter to maintain or even operate the machinery in an effective manner. Monitoring of the emissions stream is required if continuous compliance is to be assured.

Dewees (1980) suggests that all environmental programs require the accurate measurement of emissions. He argues that opposition to effluent charges on the basis of monitoring difficulties is actually an objection to vigorous enforcement.

An appropriate comparison of the monitoring and enforcement costs associated with alternative environmental programs should begin with the assumption that both schemes are being applied in a vigorous manner. Dewees (1980) suggests that given such an assumption, effluent charges may require less monitoring than a system of direct controls. In the latter case, the environmental authority monitors in order to catch violating firms. A firm in violation is prosecuted and a fine is levied, preferably an amount in line with the damage created by the violation. However, to ensure that the polluter faces an expected fine that approximates damages, monitoring would have to be very stringent.

Alternatively, with an effluent charge it is only necessary to determine the average emission rate. This can generally be done with a reasonable degree of confidence with a sample. In the latter case, the frequency of monitoring is designed to increase the precision of estimates whereas, in the former, it is actually an enforcement tool designed to encourage compliance. It appears that monitoring frequency under the charge scheme would be no greater than under an effective performance standard.

(Anderson *et al.*, 1977) suggest that the cost of monitoring should be imposed on the polluters through self-reporting in an approach compared to an income tax system. There is, however, non-symmetry here because with income taxes there exist records of transactions that can be checked by the tax department. It may be far more difficult to confirm a measurement of pollution long after the emission has taken place.

If there is an asymmetry with regard to the monitoring required for charge and standard schemes, it appears to be a result of an asymmetric approach to the rigour with which the schemes are applied. When both schemes are designed to achieve a pre-designated ambient standard, there is little evidence that requirements for charges are more excessive that those for direct controls. On the other hand, direct control schemes, which are designed to placate environmental improvements, will most definitely have an edge in terms of both monitoring and enforcement costs.

3.6 Distributional Considerations

Various studies maintain that the impact of environmental policy on the distribution of income is regressive (Asch and Seneca, 1978; Baumol and Oates, 1979). It is usually argued that environmental quality is a luxury, and thus has a relatively high income elasticity of demand. As well, the poor are less able to protect themselves from income redistributions, which sometimes accompany environmental policies.

It is difficult to deal with the first argument. The rich are willing to spend more of each dollar earned on environmental concerns. Thus any environmental improvement may yield greater gains to the rich. Any serious environmental policy that achieves a cleaner environment may benefit the rich more than the poor, which would not seem to favour one policy over another. It is ludicrous to argue that this suggests favouring ineffective policies.

The second rationale deserves more consideration. It is tempting to argue that because the financial impact of an appropriate externality price may be large, this policy will create greater income redistribution than direct controls. Indeed, such arguments have been used in favour of the direct regulation approach to environmental policies.

Adopting an environmental policy because of its impact on the distribution of income however, seems incomprehensible. Since the purpose of these policies is to improve environmental quality, not to achieve an equitable distribution of income, it seems reasonable to leave the latter to the fiscal authorities. Distributional concerns can be addressed better by other means.

Quinn (1983) believes that it seems unlikely that current environmental policy makers have adopted policies designed to advance distributional goals of the type discussed above, although he believes that the distribution of wealth is a significant factor in the choice of direct controls over externality pricing. His argument is based on two premises:

1) The political process will always attempt to maintain the status quo distribution of wealth, and
2) A redistribution of wealth using fiscal policies is politically difficult.

Quinn (1983) discusses compensation for those who lose from environmental policies. He specifically identifies labour, consumers and polluters, but not the victims of pollution. In fact, Baumol and Oates (1988) show that Pareto optimality in the face of an externality requires only a Pigouvian tax (externality price) imposed on the polluter. Optimality, in fact, rules out compensation for those who are the victims of pollution, since it may induce them to ignore the externality costs and move closer to the source of the externality.

However, Burrows (1980) takes issue with this and argues that a just solution, although it may not be compatible with an efficient solution, should compensate the receptors of pollution. Based on this theory (the current status-quo diversion) of property rights involves a reallocation of the environment, up to current standards and perhaps beyond, to polluters. A program of externality pricing would drastically change this distribution and hence would, one might argue, be politically unacceptable.

This status-quo distribution of property rights cannot, it appears, be justified on equity or efficiency grounds. In essence, under the current system some individual can use the environment free of charge thus imposing costs on others. Such political arguments appear to provide significant insights into the choice of environmental policies.

Burrows (1980: 53-54) states "…the implications of a change in property rights for the general distribution of income in society may be less important than the particular income distribution of income in society (and other welfare) consequences for the gainers and losers from the change. In fact, the legal system or pollution control agency may studiously ignore the general implications for the distribution of income, in an effort to provide protection for losers that is not dependent on income levels of parties involved in the conflict of interest."

Buchanan and Tullock (1975) provide further enlightenment on the choice of standards and charges. They use a competitive industry model to determine polluter profits under both a charge and a standard scheme. Assume there are n identical firms in a constant-cost, perfectly competitive industry. The marginal damage of pollution is assumed to be constant per unit of output. Initially each firm produces Oq_i as shown in Figure 7(a), with long-run average cost (LAC^o), price (P^o), short-run supply ($SRSS^o$), and long-run supply ($LRSS^o$). Industry output is initially $Q^o = \Sigma q_i$.

Assume the environmental authority levies a tax, t, equal to the marginal damage per unit of output. This shifts the LAC vertically upward by t at the each output level and, initially, shifts $SRSS^o$ up by the same amount. In the short run, this will result in losses and firms going out of business. As firms exit, the SRSS shifts further left until, in the new long-run equilibrium, it attains the position SRSS'. The comparative static results show that firm output remains constant at q_i, the number of firms in the industry declines to $n' < n$, industry output falls to Q', and the market price of output rises by the amount of the tax to P'.

A similar result can be attained with direct controls. The authority first determines the optimal industry output of Q' and divides it among the n original firms. This firm output is $q^o = Q'/n < q_i$. Thus under the standard each firm decreases output by $100 (Q^o – Q')/Q^o\%$. Since industry output becomes Q', the market price becomes P'(based on the market demand in (b)). Firms find themselves at a point such as A in diagram (c). At this point they are earning above-normal profits and hence there is an incentive for entry. As well, firms would like to expand output since at q^o, $p' > LMC^o$.

The policing task is much different from that needed under the charge scheme. The authorities must ensure that firms do not produce in excess of the quota (q^o) and they must also prevent new entry, otherwise the optimal level of externality (defined by Q') will be exceeded. Of course, on efficiency grounds the tax is preferred to the quota since the overall cost of producing Q' under the standard is (q^oB) x Q', whereas with the charge (ignoring charge revenue since it is a transfer) the cost is (q_iC) x Q' which, as can be seen in diagram (c), is lower.

It is clear that polluters will prefer the standard scheme to charges. Under the tax, firms incur short-run losses and regain a normal return only after exit of some firms, whereas with the standard there may even be a pecuniary gain. Indeed the quota system described is equivalent to a cartel. Despite each firm's motivation to cheat, it remains in their interest to seek regulations that enforce quotas.

However, this does not explain the popularity of quotas or standards over the more efficient alternative of charges. Buchanan and Tolluck (1975) argue that the distributional effects of charges and standards is the reason. The tax alternative yields revenues which may benefit a large heterogeneous group, whereas the quotas benefit a small, concentrated, identifiable group. Because of its size and wealth, the latter group likely has more political power, and its probable gains per decision-making unit are much greater. As Buchanan and Tullock (1975:142) point out, "the penalty tax amounts to a legislated change in property rights, and as such it will be viewed as confiscatory by owners and employees in the affected industry."

Industries often argue that charges represent double taxation: inducing abatement costs and requiring a payment for the remaining emissions. Some environmentalists consider these charges to be a licence to pollute. Large firms would continue to emit waste and just pay the charge which it passes along to its consumers. Obviously these two objectives are at odds. The available evidence, discussed earlier, suggests that appropriately set charges will be effective.

The industry will oppose effluent charges and use its considerable political power to push for a quota system. Dewees (1983) argues that, given the necessity of environmental regulation, labour and existing firms will prefer differentiated direct controls, involving stricter standards for new sources, to any of the economic incentive schemes that are currently available. Buchanan and Tullock (1975:143) conclude, "If the economist ties his recommendation for the penalty tax to an accompanying return of tax revenues to those in the industry who suffer potential capital losses, he might be more successful than he has been in proposing unilateral or one sided application of policy norms." Dewees (1983:70) concurs: "If the political process responds to interest groups that are strongly affected by a policy, the effluent charge and sale of effluent rights are in deep political trouble unless revenues are used to compensate the losers."

The chief advantage of a direct regulation policy appears to be based on the distribution of wealth. Apparently it is not a concern with the inequity of the distribution of incomes but rather a concern with the maintenance of the status quo distribution of wealth that has led to the adoption of direct controls. Far from being merely an irrelevant curiosity, the significance is that if externality prices are to be adopted, they must somehow be transformed into a more politically acceptable form, one less threatening to the status-quo distribution of wealth.

Baumol and Oates (1979) suggest that direct controls are advisable when rapidly changing environmental conditions may be heading toward an environmental catastrophe. Such conditions may not be predictable, thus making adjustments to an effluent charge uncertain. In addition, it is certainly not desirable to set charges permanently at a level high enough to guarantee environmental quality under all conditions. Direct controls have an advantage in extreme situations since they can incorporate the option of shutting down certain sources (e.g., incinerators) when air quality falls below some predetermined level. Such a direct control could be used with an effluent charge, the latter being considered a long-run measure and the former to control dangerous short-term fluctuations in the assimilative capacity of the environment.

Real-world externality pricing schemes conform well to this analysis. Most European schemes are prototypes of a German one reviewed by Brown and Johnson (1984). This effluent-charge scheme is an appendage to the existing direct regulation approach. Each source of water pollution is issued a permit which specifies standards that vary by industry and location. This permit also contains the information necessary to calculate the firm's charge payment, such as the expected concentration and volume of emissions. The charges levied in this scheme are based on the expected rather than the actual level of discharges. These are usually design standards that specify the abatement equipment that must be installed.

Discharges in compliance with minimum standards have the charge liability halved. If actual discharges (using the average of the last five observations) exceed these standards, the polluter faces legal action as well as the loss the fifty-percent reduction in the charge obligation. The revenue from this charge is used for water quality management, administrative expenses and for subsidies of waste treatment investment. Significant investment subsidies are available in most jurisdictions.

This charge scheme, like those in other European jurisdictions (e.g., Italy and the Netherlands) is primarily a revenue-raising device that is an appendage to a policy of direct regulation. For many such schemes, the charge is too low to induce compliance with standards (OECD, 1989).

The German effluent-charge scheme's main effect comes from the discount available to those who achieve the minimum standard. This, along with fines for exceeding the standard, provide the main incentives for compliance. The incentive effect of the charge itself is questionable since average control costs appear to be about four times the charge (OECD, 1989).

The primary incentive effects of the German scheme are similar to those of another form of economic incentive, the noncompliance penalty. In Connecticut, the Department of Environmental Protection has adopted a financial non-compliance penalty to supplement point source effluent standards. In essence, the authorities decide that a particular type of abatement equipment should be in place at a particular point source in order to achieve the required standard. A compliance order, along with a deadline for compliance is then issued. If the equipment is not installed by the deadline, a non-compliance penalty equal to the firm's costs savings may be imposed. The cost savings, including any profits made on this money, are calculated using a capital budgeting formula. In theory, this penalty makes compliance very attractive because compliance yields as good a return, in terms of forgone assessments, as do alternative investments.

The steps to calculate the penalty are:

(1) calculation of the relevant control technology for a given source;

(2) determination of installation, operating and maintenance costs for the technology from various engineering studies; and,

(3) translation of this cost information into a measure of the cost savings of noncompliance per period.

It is clear that real-world effluent charge schemes deviate sharply from the textbook welfare-maximizing Pigouvian tax discussed in Chapter 2, as well as the second-best cost-effective externality price discussed in this chapter. The most effective real-world externality prices are non-compliance penalties. They are designed as appendages to direct control policies and have few of the static and dynamic efficiency benefits discussed earlier.

Chapter 4

Externality Pricing in Passenger Transportation

The ultimate purpose of this thesis is to investigate the applicability of externality pricing to air pollution and noise externality problems inherent in passenger transportation. Potential and actual schemes are evaluated based on criteria discussed in earlier chapters. With respect to air pollution, transportation sources in North America contribute in excess of 47% of nitrogen oxide emissions, 71% of carbon monoxide emissions and 39% of hydrocarbon emissions (Button 1990). As well, currently in developed economies, motor vehicles contribute about 40% of total carbon dioxide emissions. (Button, 1990) Given the magnitude of transportation's contribution to environmental problems, the investigation of alternative control polices applicable to this sector is worthwhile, especially since current government regulatory programs may be adding to, rather than reducing, the problem. Chant, McFetridge and Smith (1990) state that environmental problems could be viewed as a result of government failure since it is government which fails to assign appropriate property rights. This failure often occurs because governments attempt to address other social goals (e.g. regional equity, full employment) which may conflict with environmental objectives.

With respect to transportation, Button (1990) suggests that current policy may be a result of regulatory capture, a process first discussed by Stigler (1971), in which the regulatory authority adopts policies which are beneficial to selected politically powerful groups rather than to society at large. Button argues that much of the externality policy related to transport has attempted to minimize the impact on transport users. This thinking is consistent with the positive theories of environmental regulation discussed in Chapter 3.

The automobile is the primary source of air pollution in passenger transportation and dominates the literature. There is virtually no discussion of pollution problems from air transportation, public transit or rail. Indeed, these are often considered to be part of the solution to the problem of auto pollution; diversion of passengers from automobiles to public transit would reduce pollution because there is a lower rate of emission per passenger-mile from public transit. The relevance of such solutions will be discussed in the next section.

Congestion is an issue often related to air pollution. While this thesis does not address it, it should be emphasized that optimal congestion policy may, in some situations, conflict with optimal noise and air pollution policy. As Button (1990: 62) points out, "…measures to spread traffic more evenly across an urban area or over time, may well reduce congestion but equally may divert significant traffic flows into quiet residential areas, or encourage trips at otherwise peaceful times of the day, and thus have adverse environmental effects. Environmental externalities therefore require a specific policy response."

As with air pollution, the literature on noise pollution is also dominated by a single mode, that of noise pollution at airports from jet aircraft. Part of the reason for this emphasis is feasibility: the impossibility of separating the noise according to source, the large number and variety of such vehicles, and the uncertainty of their paths and times of travel present virtually intractable monitoring problems. It is easier to monitor noise pollution with aircraft because information is readily available on flight times and paths.

It is possible to monitor the noise from traffic in particular areas. Such measures are analogous to measuring ambient air quality in air pollution problems. The use of externality pricing, however, requires that each decision-making unit's contribution to this ambient level of noise be determined. Only then can the appropriate authority design a policy which imposes the appropriate costs on those creating the problem. Traffic noise is analogous to other non-source pollution (e.g. agricultural run-off) where it is impossible to identify the exact source of the deterioration in the ambient environment. The use of an externality price would require a detailed log of the path of each trip and its time for each automobile. The charge per trip might be adjusted for time of day, location of path and the level of noise emissions from the vehicle. Of course, a scheme for automobiles or trucks requiring this amount of information would not likely be cost effective. This does not imply that public policy should not be used to address the traffic-related noise pollution problem, but only that, with current technology, an externality price is not practical.

Externality prices can take at least three forms:

1) They can be used to optimize or maximize the social surplus;
2) They can be designed to achieve a predetermined standard at least cost; and,
3) They can be used to induce compliance with given standards.

(1) Is the Pigouvian tax, (2) is the cost-effectiveness or standards-and-charges approach and (3) is basically a non-compliance penalty. From society's point of view, the net benefits of these schemes decline from (1) to (3), but so do the informational requirements. Therefore ranking of these policies when informational requirements are considered may change depending on the specific situation. The last two sections of this

chapter look at possible gains or losses from variants or combinations of these forms of externality pricing, first for automobile air pollution, and then for airport noise pollution.

4.1 Air Pollution

The efficacy of current policies to control air pollution from transportation sources, especially the automobile, has been widely questioned in economics literature. The major concerns are the inflexibility of regulations across regions and the lack of incentive for technological change. A first-best Pigouvian tax cannot be imposed on auto pollution because of uncertainty surrounding the damages of pollutants from automobiles. Still, some form of second-best externality pricing might improve upon the current situation.

As suggested in Chapter 3, there are significant flaws in the direct regulation approach. Its inherent incentive to delay compliance has obviously characterized the North American auto industry for at least two decades. Of course, past problems with the program do not mean that it is failing today. After all, hydrocarbon emissions have decreased relative to their 1970 levels by 20%, 40%, and 78%, despite an estimated 58% increase in vehicle-miles traveled (Crandall *et al.*, 1986).

To determine whether an alternative approach would yield significant advantages one must examine the current and projected problems of the program. This chapter begins with an investigation of the problems inherent in the current regulatory approach. Some alternative schemes are then presented and evaluated. Finally, a survey of economic incentive policies used to alleviate passenger transportation air pollution problems is provided.

4.2 Performance Problems with the Current Regulation Approach

Crandall *et al.* (1986) lists several defects of the current performance standard approach used in Canada and the U.S.:

- Current regulation imposes more stringent standards for new cars, which prolongs the life of used cars by reducing the incentive to scrap them. Since old cars are "dirtier" cars, this may cause adverse short-term effects on emissions levels (Gruenspect, 1982). Thus the form of regulation on new sources used to regulate auto pollution depends for its success on changes in the composition of the fleet. An increased scrapping rate is crucial to its success.
- The punishment inherent in current regulation is too severe. Preventing a major manufacturer from marketing a line of cars is not a credible threat. As a result, the history of environmental regulation in the auto industry has been one of delays and postponements.
- New source performance standards provide no incentive for owners to maintain the emissions devices on their automobiles. While manufacturers are required to provide five-year 50,000-mile warranties on this equipment, there is little incentive for drivers to exercise this option because they are not liable for poor performance.

These are apparent structural flaws, but what of the scheme's performance in practice? The ultimate objective of the program was to reduce suspected severe health risks from photochemical oxidants (smog) formed as a result of a complicated chemical reactions between HC, NO and sunlight. However, because it is difficult to evaluate the program directly on this basis, it is more reasonable to look at aggregate emission rates and ambient air quality (Khanna, 1999).

The EPA has produced models to predict aggregate emissions from automobiles over time. These emissions depend not only on new source standards, but also on other variables such as the composition of fleets by model and vintage, total miles driven, and distribution of mileage. Between 1970 and 1982, despite a 31% increase in vehicle-miles traveled, emissions of HC, CO and NO_2 fell by 54%, 45%, and 10%, respectively (Crandall *et al.*, 1986). As the phase-out of earlier models continues, this performance will improve. This improvement is clearly the result of the regulatory program rather than some exogenous technological change.

On the negative side, however, these improvements in emission rates are somewhat below the 90% reduction in emission legislated in the U.S. Of relevance here is how the in-use emissions of cars will respond over time as older, "dirtier" cars disappear. Random tests of in-use vehicles by the EPA show that the shortfall between legislated standards and in-use performance would not only continue, but also increase.

Ultimately, there is a closer relationship between damages and air quality than between damages and emissions. Therefore, information on the effects on air quality of a regulatory program is important to its evaluation. Such data is scarce because very little intensive monitoring of emissions from industrial, utility, or mobile sources has been carried out by region. As a result, it is difficult to attribute improvements in air quality to any specific source or program. This is surprising given the cost of automobile emissions programs.

However, the problem of attributing air quality in a particular region to a particular emission reduction program goes beyond lack of data. Varying meteorological factors from region to region affect how emissions reductions are translated into ambient quality improvement. As well, there is a complicated nonlinear relationship between emissions of HC, NO_2 and the creation of smog.

The available evidence on relevant air pollutants shows relatively little, if any, change in ozone at monitoring sites. With respect to ambient CO, there have been significant improvements in concentration levels in urban areas between 1975 and 1983, which are likely attributable to automobile control policies.

The main conclusion drawn from this information is that the current automobile pollution control program in the U.S. is not very effective. After comparing three U.S. regulatory programs related to the automobile—fuel, safety, and emissions regulation—Crandall *et al.* (1986: 157) conclude that the automobile emission control program "…is the most inefficient and poorly designed of the three regulatory programs analyzed." It may also be too costly due to failure to incorporate differences in regional (urban/rural) air quality.

U.S. environmental laws (and Canadian ones by extension) are designed to solve pollution problems in extremely polluted urban areas such as Los Angeles and Denver. Because such standards are surely not cost-effective in most rural areas, it may be more reasonable to allow higher emissions there than in heavily populated areas. It is difficult to argue that there are positive net benefits from such programs in rural regions.

This factor, automobile emission rates which deteriorate quickly with age of a car differential regulation problems, and the lack of credible sanctions in the program suggest a need for change to the regulatory approach. Particular attention should be paid to the local nature of damages.

4.3 Alternative Control Schemes

Several variants of two schemes have been suggested as alternatives to supplement the current direction of the regulatory approach:

- Limit the use of automobiles in urban areas through restrictions or subsidies to alternative modes of transportation; and,
- Use externality prices to achieve desired emission levels in new and used cars.

Increased parking fees, larger subsidies to urban mass transit and increased investment in mass transit have all been suggested as ways to induce a shift from the automobile to public transit, with the resulting reduction in pollution, noise and congestion levels in urban areas. Analyses of such schemes (Dewees, 1974 and 1976) have found them to be largely infeasible for a number of reasons:

- The low numbers of commuters who use public transit. Dewees (1976) reports that 10% of all urban passenger trips in North America are by public transit. In Toronto this becomes 20%.
- A low cross elasticity of demand between modes. Button (1990) found low cross elasticities for peak road traffic in London of 0.25 with respect to bus fares and 0.056 with respect to rail fares. As well, he notes that an experiment with free public transit in Rome in the early 1970s had a negligible impact on auto traffic. Dewees (1976) estimated that free transit in North America

would increase ridership by 30% which, given urban transit ridership of say 10%, would lead to a slightly more that 3% diversion of automobile traffic.

A study of various local pollution policies was undertaken in Boston in the early 1970s. The model incorporated data on traffic flows, aggregate emissions and air quality at 123 receptors (Tietenberg, 1988). The alternative policies considered were a 10% reduction in transit fares, a vigorous program of transit extension and the adoption of 1980 emissions standards. It was assumed that these standards would be met immediately although, in reality, it may take some time to achieve such standards.

The results suggest greater reduction in emissions from the new source standards (Sims, 1992).

Table 2:

Emissions (gms/sec)	**Benchmark**	**Fare Reduction**	**Transit Extension**	**1980 Emission Standards**
CO	19, 609	19, 343	19, 497	4, 022
HC	2, 755	2, 711	2, 744	485
NO_2	934	919	933	401
Annual Costs ($1000)	0	11, 517	95, 083	120, 000

Although fare reductions dominate the transit extension option, neither improves the environment significantly. It appears that local policies of this type are of limited use and should only be used to respond to special local needs.

A number of studies (Dewees, 1974; Tietenburg, 1990; 1988; Baumol and Oates, 1979) suggest that externality pricing could play an important role in automobile control policy. Such a policy represents a change in philosophy since the owner of the car rather than the manufacturer effectively becomes responsible for the emissions from his or her car. Indeed, there are a number of reasons why externality pricing might be well-suited to help control auto pollution:

- The history of direct regulation of auto pollution has been one of delays and postponements. A charge scheme could induce greater technological change.
- As Dewees (1974) and Tietenburg (1988) suggest, the marginal cost of control at present abatement levels is quite high. Indeed it is relatively constant up to abatement levels of 50 percent and then rises steeply. Charges would be preferable to standards since with cost uncertainty, the former places an upper bound on costs.
- Tietenburg (1990:30) argues that when comparing charges with a property right scheme, "emissions charges work particularly well when transaction costs are high…For this reason charges seem a more appropriate instrument when sources are individually small, but numerous (such as residences or automobiles). Charges also work well as devices for increasing the rate of adoption of new technologies and raising revenue to subsidize environmentally benign projects."
- The current regulatory program is not particularly cost effective. Tietenburg (1988) notes that the cost per ton of HC abatement resulting from the inspection and maintenance program in the U.S. was two to three times higher than an equivalent reduction at stationary sources. This suggests that an externality price for mobile sources, if properly co-ordinated with abatement at stationary sources, could yield significant cost savings over the current program. As well, as concern with global pollutants such as CFCs and CO_2

grows, the cost advantage of a single externality price for mobile and stationary sources becomes more evident.

- Dewees (1974) also argues that current standards impose higher marginal control costs on some vehicles than others because emissions vary with weight and transmission type. This means that the current scheme is not even cost effective when evaluated only within the context of the fleet.
- Monitoring requirements for an effective externality-pricing scheme are no more severe than those of the direct regulation regime. For example, New Jersey currently tests the exhaust emissions of every car as part of an annual inspection. The test only takes about 30 seconds (Baumol and Oates, 1979).

Among the first proponents of a charge related to auto pollution emissions were a group of economists from the Rand Corporation (Baumol and Oates, 1979). Their suggestion, known as a smog tax, involved regular inspections of a car's exhaust and a resulting assignment of a smog rating. A car's smog rating would determine the price paid by the motorist for a gallon of gasoline. The motorist could reduce personal tax payments by maintaining the car's pollution control equipment, reducing the mileage driven and retrofitting an older model car to reduce emissions.

Dewees (1974), however, rejects the use of a tax on gasoline consumption, arguing this might only affect motorists' choice of vehicles, and may not reduce overall emissions. Instead, he suggests a charge that would vary with the emissions of a particular pollutant per mile. This would give the driver an incentive to seek out less pollutant-intensive vehicles. The charge could be adjusted according to location or region.

Because an annual measurement of emissions from every automobile might prove costly, the challenge is to find an alternative solution that avoids these administrative costs while maintaining the character of the charge described above. The solution Dewees suggests is first to estimate the lifetime of emissions of a model in a particular year and then to levy a charge per unit of the relevant pollutants (lead, HC, CO, NO_2).

As well, random tests of cars on the road could be undertaken to observe the deterioration of the pollution control equipment. Any significant change for a particular model or engine class could result in an adjustment of the tax. This scheme provides adequate incentives for technological change by providing a competitive advantage to a manufacturer -the cleaner the car, the lower its sale price. In-use testing would also encourage manufacturers to provide more durable products.

Not all vehicles would be controlled to the same extent under this scheme, across or within jurisdictions. Within a jurisdiction, cars with relatively high abatement costs would abate less and incorporate higher externality price costs within their sale price. In addition, in low-charge jurisdictions, more pollution-intensive vehicles would be sold. Monitoring requirements in this scheme are no more severe than under the current regime. This scheme does not specify the standards to which a car must be built; it only levies an externality price that is captured into the price of the vehicle so cost effectiveness would result.

High–damage regions may wish to levy an additional charge on vehicles at the time of annual registration of the auto. The charge, which could be based on emission/mile rates and the odometer reading, would encourage drivers to purchase clean automobiles and to maintain the control equipment. Alternatively, it would encourage owners of “dirty” cars to drive them less, scrap them earlier, and consider retrofit abatement equipment. The drawbacks of this scheme are the need for sealed odometers and increased monitoring costs.

The advantages of this externality pricing scheme are that manufacturers would no longer have an incentive to delay or postpone innovations. The perverse incentive effects of differentiated regulations would disappear, and the owner of the car would have an incentive to maintain control equipment and/or take advantage of the manufacturer’s warranty. As well, an externality price differentiated by region (eg., urban versus rural) would likely be more cost effective.

4.4 Economic Incentive Schemes

There are few incentive schemes used to control pollution from mobile sources and none in existence as comprehensive as the one described in the previous section. Button (1990) discusses a differential annual automobile tax in Germany. Also used in the Netherlands, this tax is reduced for automobiles that meet European Community environmental standards. In both countries cars are classed in one of three categories: clean cars, restricted-clean cars, and other cars. The cleaner the car, the greater the tax advantage. However, all of these schemes are merely minor elements in a larger package dominated by the direct regulation approach.

4.5 Noise Pollution

The environmental problem that attracts the most attention in urban areas is the loss of peace and quiet, particularly near expressways and airports. As Gillen and Levesque (1990) point out, this is one of the major impediments to airport expansion.

Noise is a public "bad" in much the same way as air pollution. It interferes with the well-being of people through no fault of their own. It is a by-product of a productive process and results in the reduction of a scarce resource and valuable asset: peace and quiet. Because ownership of the property right to this asset is undetermined, it is treated as a free good. Airports and airlines that use this scarce asset do not incorporate its value into their cost or profit calculations, and thus tend to consume too much of it. That is, they create too much noise.

The damage caused by noise includes loss of sleep, loss of relaxation, and interference with conversations and television reception. While it is also possible to attribute hearing loss to loud noise, this seems an unlikely outcome of the type of ambient noise considered here. Thus the chief impact of noise on those living near airports or expressways involves annoyance rather than health damage.

Noise pollution around airports has grown worse in recent years because deregulation has substantially increased airport activity. At Pearson International Airport in Toronto, traffic increased from 250, 000 to 350,000 movements between 1985 and 1988. This, along with continued urban growth, has exacerbated the problem.

Despite this, the economics literature dealing with noise pollution remains somewhat underdeveloped when compared to that dealing with other environmental problems. While the noise pollution literature exhibits some similarities with the pollution literature reviewed in earlier chapters, there is a significant difference in the approach developed by at least one author. Harrison (1983) argues, what amounts to a first-best Pigouvian tax can be used in the case of noise pollution at airports. This appears to be one of the few areas of the environmental literature where this first-best scheme is of direct relevance.

This section describes the regulatory approach that currently dominates in North America, reviews some alternative economic incentive schemes suggested in the literature and summarizes noise pollution charge schemes presently in use.

4.6 Current Regulatory Approach to Noise Pollution at Airports

Regulations to reduce aircraft engine noise have been introduced by both the U.S. Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO), and these regulations have had a significant impact in the operation of aircraft in Canada. In 1969 the FAA introduced the Federal Air Regulation 36, requiring new commercial planes to conform to certain prescribed standards with regard to noise emissions. Standards are set for take-off, landing, and sideline noise and aircraft not meeting standards are denied certification. In 1976 jet aircraft in service were required to meet these standards whether by retrofit or replacement. As well, in 1970 ICAO adopted Standards and Recommended Practices for Aircraft Noise (Annex 16). Member states, such as Canada, that accept the provisions of the Annex incorporate its requirements into their own national legislation. Similar in tone to Part 36, Annex 16 was first applied in 1972 to provide noise certification for jets. Different provisions apply to different planes depending on weight and time of production. New planes are subject to stricter standards. Annex 16 is the basis for certification of airplanes in Canada.

Noise is measured in decibels (dB), a measure of intensity derived from a logarithmic transformation of sound energy (Starkie and Johnson, 1975). Noise emissions from individual aircraft are measured in effective perceived noise decibels (EPNdB). This scale incorporates several modifications to the dB scale to account for how people perceive the noise from an aircraft during an entire flyby. In addition to aggregating this noise, the EPNdB scale incorporates weights which account for the greater annoyance attributable to noise than pure tones.

While EPNdB is meant to represent the subjective annoyance produced by the operation of a single aircraft, it is necessary also to have a cumulative or ambient measure of noise produced by all activity over some time period. The Noise Exposure Forecast (NEF) is designed to represent cumulative noise levels during a 24-hour period at a particular site.

The noise standards imposed on aircraft in North America represent a classic application of the direct regulation approach. Here, as with other environmental problems discussed under the direct regulation approach, its history is characterized by delays, postponements and modifications, especially in the U.S. The major concern of airlines has been the extension of Part 36 standards to existing fleets. Also referred to as the retrofit rule, it requires retrofit of Stage 1 aircraft within a specified period. Aircraft certified under the original Part 36 standards were called Stage 2 aircraft. Stage 1 aircraft are those not subject to the Part 36 standards. Opposition to retrofit is noted by Harrison (1983:64): “through the Air Transport Association, the airlines have steadfastly opposed the Part 36 extension, arguing the benefits are not commensurate with costs, that the compliance schedule was impossible to meet (because of the limited availability of retrofit kits and the airlines' limited resources), and that the requirement would compromise fuel efficiency and safety objectives."

Based on such arguments, Congress extended the schedule for planes with two or three JT8D engines, an interesting development since these are the most cost-effective engines to retrofit (Harrison, 1983). This compromise was chosen in order to reduce the impact on smaller airlines, but obviously did so at the cost of efficiency.

4.7 Alternative Control Schemes

Several alternative charge schemes have been suggested in the literature. Nelson (1978) derives a set of landing charges designed to induce retrofit. He first determines the cost of retrofit per landing or per unit of noise emissions (EPNdB) reduced and uses this to define the relevant tax or externality price. For example, assume an airline is charged a noise fee for every landing of every non-retrofit aircraft. P, the charge per landing, which induces retrofit by the relevant aircraft types can be defined using:

$$P \text{ x } L = C / \sum d_t$$

where L is the number of landings per year, C is the present value of retrofit costs, $d_t = 1/(1+r)^t$, r is the rate of interest, and n is the remaining economic life of the plane. Therefore,

$$P = C/L[\{r(1+r)^n\}/\{1+r)^n - 1\}]$$

Thus, using sound absorption material (SAM) on a B-707 that cost \$1.417 million dollars in 1975 dollars (Harrison, 1983) and assuming a 10-year economic life with 1,000 landings per year and a 10 percent discount rate, P equals \$231.

Nelson also calculates an implicit marginal cost per EPNdB abated. Since the retrofit reduces, on average, the EPNdB from a B-707 from 116.8 to 104, the marginal cost (MC) is:

$$MC = P/\Delta EPNdB = 231/12.8 = \$18.05$$

Nelson finds that these charges vary from \$301 for a B-707 to \$35 per landing for a B-727 or, in terms of the implicit cost per EPNdB reduced, from \$4.43 for a DC-10 to \$22.67 for a DC-8. Thus a charge of \$25 per dB of noise emissions in excess of the legal standard would induce retrofit because a non-retrofit B-707 has an average noise level of 116.8 EPNdB. This would result in a landing charge of:

$$\$25(116.8 - 106.3) = \$262.50$$

The discounted cost per landing of retrofit for a B-707 was shown above to be \$231.

The scheme presented by Nelson (1978) is similar to the non-compliance penalty discussed in Chapter 3. Its purpose is to introduce some flexibility into the standards scheme. Airlines, for example, may choose not to retrofit older planes that will be retired in the near future. This may prove to be cost effective. If older planes are retrofitted now, their economic lives may be increased. Alternatively, under this non-compliance penalty, newer, quieter planes may be adopted sooner. While in the short run noise may not be reduced as much under this scheme, the long-run impact may involve less noise at a lower overall cost.

This scheme does not result in airlines delaying retrofit when it is a feasible option. Also, since the charge is based only on retrofit, it really requires little or no noise monitoring. Planes which have installed retrofitting do not pay the charge; those that have not pay a charge which is related to the economic benefit to them of non-compliance.

However, this scheme has several drawbacks. There are a number of ways of reducing sound damage: reduction of noiseless of aircraft engines, changes in aircraft landing and take-off procedures, changes in the timing of aircraft operation, and soundproofing homes near airports. Since the non-compliance penalty deals with only one of these control techniques, it is unlikely to be cost effective or to provide any more incentive for technological change than the standard approach.

Harrison (1983) discusses a different approach to the externality pricing of noise pollution. He argues that there is sufficient evidence to suggest that the airport noise damage function is linear over the relevant range. This condition, if correct, would allow the use of a theoretically correct Pigouvian tax.

Harrison offers other reasons for at least an experimental use of charges to control noise pollution. Unlike other environmental problems, the benefits of noise reduction do not seem to require a determination of the value of life and limb since health effects are not a relevant component of damages from ambient noise. As well, monitoring of noise at airports does not appear to be a major problem. Indeed, with the exception of Dorval Airport in Montreal, all major Canadian airports already have monitoring facilities (Gillen and Levesque, 1990).

To impose this externality tax, the marginal damage of noise or the marginal benefit of noise reduction must be determined. As Harrison points out, the information required to do this is already available in a number of hedonic house-price differential studies. When people purchase a house, they also purchase the amenities and disamenities of the neighborhood in which it is located. Given two identical homes, A and B, alike in all respects except that A suffers from the noise generated at an adjacent airport, it is expected that in equilibrium the price differential between A and B will represent the capitalized annual value of damages caused by this noise.

In a summary of 13 empirical studies of aircraft noise and housing prices, Nelson (1978) finds that the mean noise discount of housing prices is 0.62% per unit increase in NEF and ranges between 0.4 to 1.1% in these studies. The annual present value of these damages can be derived by applying a discount factor. For example, a $100, 000 home when situated near an airport would fall in value by $100 000 x (0.62%) = $620. The annual damage caused by the annoyance of noise is $62 assuming a discount rate of 10%.

A study by the Council on Wage and Price Stability, reported in Harrison (1983), estimates that, in 1975, noise-associated damages near airports in the U. S. amounted to $325 million/year. These results are based on the Nelson study as well as estimates on the number of people in the U.S. exposed to airport noise levels greater than NEF 30. This is the threshold value below which noise is no longer considered a nuisance. Assuming that 98 EPNdB corresponds to NEF30, using data on the number of airplane operations by various types of planes, and calculating the resulting noise levels, it is possible to determine the number of EPNdB's emitted above the threshold. In 1975, this was approximately 45 million. As a result, a uniform national charge of $325/45 = $7/EpdB would represent marginal damages from noise.

Harrison points out a number of problems with a uniform national charge of this type, not the least of which is that it does not provide a good proxy for the marginal damages of noise. The uniform scheme assumes all EPNdBs cause the same annoyance. There is evidence, however, that the damages of an additional unit of emissions will vary with airport location, time of day of the emissions and even the level of EPNdB emissions.

It is noise exposure with which we are ultimately concerned, not noise emissions. The best basis for setting a noise charge, as well as measuring noise exposure, is NEF levels. If an aircraft taking off from airport X increases NEF levels on average by 0.5 for 1,000 households, the airline would be charged for 500 NEF-households. The problem with this measurement is the complexity of the calculation.

An alternative suggested in Harrison (1983:75) is to devise a formula that incorporates these major variations. He presents various average noise charges for selected U.S. airports based on a general form:

C = F (EPNdB, t, A),

where C is the noise charge, t is the time of day, and A the airport. “The schedule…is based on a doubling of the area exposed to a given noise level with every increase of 5 EPNdB, a twelvefold penalty for the 'nighttime' operations (10:00p.m. – 7:00 a.m), and separate calculations of the noise damage at each airport.”

Two major limitations of the retrofit approach are that all aircraft must comply despite that fact that compliance may not be cost effective for some planes. The retrofit scheme concentrates on only one way of reducing noise exposure to the exclusion of others, as does the noncompliance penalty discussed earlier. Both the uniform charge and the noise charge formula overcome these weaknesses. Since, based on Nelson (1978), the cost of retrofit between types of aircraft varies by a factor of six, it is clear that these charges can increase cost effectiveness. Airlines have the choice of retrofitting or not, or choosing some other means of abatement, such as operational changes.

It is also expected that the noise charge formula will be more cost effective than the uniform charge because there are certain methods of noise control which the firm will be induced to consider under the formula. These include the reduction of night flights and alteration of airports.

The direct regulation approach is often criticized because it provides little or no incentive to adopt innovations that reduce emissions below the standard. It may even provide perverse incentives to produce costly, ineffective technology due to the pressure of deadlines. Harrison (1983:105-6) suggests that this has affected innovations in the auto industry: "Automobile emissions are often cited as a case in point. Many commentators believe that the 1975-76 deadline established in the 1970 Clean Air Act for a 90% reduction in emissions forced the automobile companies to choose high-cost, unreliable, 'bolt-on' technology rather than a lower-cost technology that would necessarily have been ready for production for the deadline."

An effluent charge might have resulted in a durable technology, which might have achieved abatement in excess of the 90-percent goal. Similar problems can be envisaged resulting from the retrofitting regulatory approach to airplane noise control and its forced deadlines.

As discussed in Chapter 3, the revenues derived from these charges provide one of the main obstacles to their acceptance by polluters. Despite the cost savings which would accrue under the charge, the tax payments made by airlines would probably erase these savings.

It has been suggested that these charge schemes are less likely to be opposed if the revenues are earmarked for noise-related purposes. As Harrison points out, however, such uses may lead to expenditures, such as soundproofing homes or compensation for those close to airports, which are ineffective, wasteful and inequitable. As well, often these programs are designed merely to dispose of the revenues generated. Several studies including Harrison (1983) show that soundproofing residences is not as cost effective as alternative abatement techniques, and that it is difficult to determine reasonable equity criteria concerning who should be compensated for noise pollution from an airport. Recent arrivals to the area likely purchased homes at a discount because of the ambient noise in the neighborhood. That is, the real loss was probably suffered by the original home owner.

4.8 Economic Incentives Schemes

A number of countries have adopted noise effluent charges at airports, including France, Germany, Japan, the Netherlands, and Switzerland (OCED, 1989). Virtually all of these charges stem from an attempt to compensate those who live in the vicinity of airports. The Japanese and Dutch charges, used ultimately for soundproofing homes and relocating families, are set at a rate to recoup the cost of these noise impact-reduction measures. The Dutch charge varies by type of plane and time of day, but it is not set high enough to induce airlines to install noise reduction equipment (Kneese *et al.*, 1977).

The OECD has suggested implementation of a hypothetical noise charge. The OECD scheme, unlike any of the existing ones, incorporates incentive effects. A standard for each type of jet aircraft is set below the level that could be achieved with the best available control equipment. Each jet is also given an uncontrolled noise rating. Each time the plane lands, it must pay a charge based on the amount by which its noise emissions, measured in dB, exceed the standard. These noise emissions are determined by the type of aircraft and the noise reduction equipment installed. Designed to induce further innovation, the charge is set high enough to induce the installation of the best retrofit equipment available. The revenues from the OECD scheme are used to compensate the victims of noise pollution directly. Presumably they are allowed to decide how to spend this money (Kneese *et al.*, 1977).

It is interesting to note that nearly all real-world schemes, as well as the hypothetical OECD scheme, are designed in some way to compensate the victims of noise pollution. This runs counter to the recommendations of Baumol and Oates (1988:23) who argue that "…if all the neighbors of factories were paid amounts sufficient to compensate them fully for all damages…obviously no one would have any motivation to locate away from the factory." Their opposition to compensation does not, however, rule out a re-allocation of the revenues received from charges. It only suggests that such a re-allocation should not be based on the damage sustained by victims of pollution.

With a Pigouvian tax, the optimal charge is levied against the polluter—in this case airlines—and no subsidy is paid to victims. The result under certain conditions is optimal, but says little about equity. The victims will, in this solution, undertake the optimal amount of defensive action. If they are compensated for annoyance, their incentive to do something for themselves is weakened. The problem is similar to the moral hazard problem discussed in the insurance literature. If victims are fully compensated for a theft, they have little or no incentive to allocate resources towards burglar-proofing their homes. Baumol and Oates (1988) argue that this may result in entry into the "victim activity." In the aircraft noise example this would mean too many homes located close to airports.

A simple example can help to explain the distortion which compensation may induce. Assume that an individual lives close to an airport and is annoyed by the resulting noise. Assume also there is some action that the victim can take that will totally alleviate the annoyance, resulting in quiet, Q_i. He or she will only undertake this action if the reduction in damages exceeds the costs of the action. Assume the individual does nothing; then the individual, whose preferences are represented in Figure VIII, will be at point A, consuming Q_o quiet and with income Z_o. The noise exposure-control technique available must cost less that $Z_o - Z_1$ or the victim will not adopt it. Assume it costs $Z_o - Z_2$ per period. The victim will adopt the device since it will raise his or her utility from I^o to I'.

Now assume the government decides to compensate the individual for damages suffered. These damages, with the monetary value of $AE = Z_3 - Z_o$ would make the victim as well off as he or she would have been had there been no noise. Provided the victim expects this compensation to continue, he or she has no incentive to undertake any defensive action to alleviate the noise. This is likely not an optimal result.

Burrows (1980) agrees with this result on grounds of justice. He argues that to allow "optimal" levels of pollution with no compensation to victims may be unjust. On the other hand, to reduce pollution levels to zero or to compensate victims may be inefficient. Thus a just and equitable solution may involve some compensation and a resulting loss of efficiency. Burrows (1980:105) suggests that is may be possible to limit these losses:

> "In practice it will be difficult to distinguish between cases of pollutees who, despite taking care, are suffering high damage levels owing to their own sensitivity, and those who expose themselves to such damages knowing they will qualify for more compensation. The result may be a need to approximate full compensation by defining "reasonable" sensitivity and "reasonable" care taken to avoid exposure, and basing uniform payments to pollutees on the damage associated with reasonable pollutee behavior. This is, of course, exactly what the courts have in mind when they relate damage awards in tort cases to the loss that would have been suffered by the 'reasonable man.'"

CHAPTER 5

Conclusion

Negative externalities involve actions by agents that impose costs on others. Because the market provides no incentive for agents to take these costs into account externality prices can be charged to force firms to internalize these external costs. An alternative device prevalent in North America is direct legislation. Under this scheme the government legislates the amount of damage that a firm is allowed to impose. Externality pricing has a distinct informational requirement advantage over direct regulation because it requires no knowledge of abatement costs, whereas the authorities require knowledge of both marginal damages and marginal costs in order to determine standards.

This apparent advantage is neutralized to some degree in real world situations. When damage functions are non-linear, knowledge of both damages and costs is necessary for the externality price scheme as well. If the location of the damaging firms is relevant, one externality price is not optimal because the damages imposed are not equal in cost. Thus every polluter would be charged a different externality price based on its damages. The informational advantage still holds regardless of the number of polluters and their marginal damages, but only if the functions are linear.

When abatement costs are uncertain, standards dominate charges as the optimal solution. The welfare loss from charges and standards are equal only when the elasticity of damages and abatement costs are identical or when the authority knows the actual value of marginal abatement costs. Additional problems arise in the case of imperfect competition. Externality pricing causes a monopolist to reduce its already restricted output, thus creating a welfare loss for society. Depending on the size of damage savings and the welfare loss, society could be made worse off. Non-convexities also create problems for externality pricing. When concave functions are examined, we can no longer be certain if an externality price or a standard will lead to a Pareto optimal outcome.

There are a number of reasons to doubt the ability of a regulatory agency to use optimal externality pricing. With current levels of knowledge we are unable for most pollution problems to say much about the location or level of the marginal damages of pollution function. An optimal externality price requires knowledge of not just current marginal damages, but the marginal damage at the optimal emission level.

As a result, a satisficing approach is used by government agencies that imposes standards and adopts the most effective policy available to achieve their objective. Economists see the externality price as a possible policy to achieve the goals of this approach. The authority will choose a policy that achieves the standard in the least costly way. Evaluation depends on allocative and dynamic efficiency, informational requirements, and political acceptability.

Direct regulation is used almost exclusively throughout North America. Ambient and effluent standards are set and enforced by the threat of fines and/or imprisonment. This scheme also often includes some form of financial assistance to help the polluter comply with the objectives.

However, the direct regulation approach can be described as symbolic. Tough standards are often set but not enforced. Exceptions are made through negotiation and deadlines are deferred. The direct regulation approach has not been very successful in persuading polluters to comply with abatement schedules. Instead of providing an incentive to abate, direct regulation provides an incentive to delay expenditures. Firms face a very small risk of prosecution.

The opportunity for delay has led to a lack of progress in pollution control. Also the direct regulation approach fails to provide an incentive for innovation or advancement. Direct regulation usually sets stricter standards on new sources, which prolongs the life of older, more emission-intensive vehicles.

Tax provisions provided under the direct regulation framework can also lead to inefficiency because only certain forms of investment are included. Firms choose the abatement technique that minimizes private costs, but not necessarily those of society. Tax concessions are also inequitable because they provide more aid to firms that pay higher taxes, providing the least support to those who need it most.

Many economists believe that externality pricing is superior to direct regulation. If an effluent charge is designed to achieve a predetermined level of abatement, there is no incentive to delay the installment of abatement equipment. While failure to install equipment does result in cost savings, it also results in larger effluent charges. The effluent charge scheme is a more decentralized method of control. Once the charge is set, firms decide how to reduce pollution emissions and will obviously do so in the least costly manner. Under direct regulation, this may not be true because often firms are required to adopt a particular abatement technology that may not be the least costly approach. Since effluent charges induce technological change in abatement techniques they are also more efficient in a dynamic sense. Monitoring and enforcement has been shown to favour neither direct regulation nor pricing schemes.

Although environmental policy has a regressive impact on the distribution of income, adopting an environmental policy on a distributional basis seems quite incomprehensible since the purpose of the policy is to improve the environment, not achieve equity. However, the distribution of wealth is a significant factor in why authorities choose to use direct controls over externality pricing. Because externality pricing changes the distribution of wealth it is often politically unacceptable.

Polluters favour standards because they allow them to delay compliance and collect tax concessions. Because of industry size and wealth, they will likely have political power enabling them to influence decisions. If the political process responds to interest groups, externality prices will not likely be used. This is why most real-world externality schemes take the direct regulation approach.

Non-compliance penalties are popular for supplementing direct control standards. Authorities decide on a particular type of equipment that should be in place to achieve its required standard, and if not installed by a certain deadline a penalty is imposed. The most effective real-world externality price is the non-compliance penalty.

The ultimate purpose of this thesis was to investigate the potential applicability of externality pricing to air pollution and noise externality problems inherent in passenger transport. This investigation is worthwhile given the magnitude of transportation's contribution to environmental problems and the fact that government regulation may be adding to the problem. Major concerns in the area of air pollution from automobiles are the lack of flexibility, and incentive for technological change.

There are several defects in the regulation approach to automobile pollution. Current regulation imposes more stringent standards on new cars, which prolongs the life of used cars by reducing the incentive to scrap them. The punishment inherent in current regulation is also too severe. As a result, the history of regulation in the auto industry has been one of delays and postponements. Lastly, source performance standards provide no incentive for car owners to maintain the emissions devices on their automobiles because they are not liable for poor performance. The current automobile pollution control program is not very effective and there is a need for change in the regulatory approach.

Several alternatives have been suggested including subsidies to mass transit. However, analyses of such schemes has found them to be largely infeasible because of the low numbers of commuters who use mass transit and the low cross elasticity of demand between modes. Externality pricing could play an important role in automobile control policy. Such a policy would represent a change in philosophy since the owner of the car rather than the manufacturer becomes responsible for the emissions from his or her car. A charge scheme also induces greater technological change and increases cost effectiveness.

The charge would vary with the emissions of a particular pollutant per mile and be incorporated into the sale price of the vehicle. An estimate of the lifetime emissions of a model in a particular year would be calculated and then a charge would be levied per unit of relevant pollutant. Random tests of cars could be taken to observe the deterioration of pollution control equipment, and any significant change could be reflected in an adjustment of the charge. This would give the driver an incentive to buy less pollutant-intensive vehicles. This scheme also creates incentives for technological change by providing a competitive advantage to manufacturers of clean cars. This scheme also provides flexibility because it does not mandate how a car must be built, so manufacturers are able to use least cost methods to control emissions. Manufacturers would have no incentive to delay or postpone innovations, and the owner of the car would have an incentive to maintain the equipment.

Noise pollution around airports has grown worse in recent years due to deregulation of airlines, and urban growth has exacerbated the problem. Current regulations to reduce aircraft engine noise have been in the form of prescribed standards. These are mostly in the form of retrofit or replacement of engine parts. The noise standards imposed on aircraft in North America represent a classic application of the direct regulation approach.

Several alternatives have been suggested to improve the efficiency of noise pollution policy. Landing charges designed to induce retrofitting could be used. The cost of retrofit per landing or per unit of noise pollution reduced could be used to define a landing tax or externality price. The airline would then charged a noise fee for every landing of a non-retrofit aircraft. This scheme is similar to the non-compliance penalty, but only induces retrofitting of relevant aircraft. Under the current approach older planes have to be retrofitted, thus increasing their economic lives. Under the non-compliance penalty, newer, quieter planes may be adopted sooner resulting in less noise in the long-run at a lower overall cost. This scheme does not result in delaying retrofit when it is a feasible option; and, because the charge is based on retrofit, it requires little or no monitoring.

However, this scheme does have drawbacks, it deals with only one noise control technique and is unlikely to be the most cost-effective way to reduce noise. Changes in landing times and soundproofing homes may prove less expensive. It is also unlikely to provide any more incentive for technological change than the standards approach.

Noise pollution from airports seems to be one of the few areas where a Pigouvian tax can be used effectively. There is significant evidence that the airport noise damage function is linear over the relevant range. If true, this would allow the use of the theoretically correct Pigouvian tax. The two major limitations of the retrofit approach are that all planes must comply despite the fact that compliance may not be cost effective and in some cases, the retrofit scheme concentrates on only one way of reducing noise exposure. A noise charge would overcome both of these weaknesses. This externality charge would also increase cost effectiveness because airlines would have the choice of retrofitting or choosing some other means of abatement.

A number of countries have adopted noise charges in an attempt to compensate those who live in the vicinity of airports. These charges are used for soundproofing homes and relocating families. This is contrary to the view of economists who believe that if victims know they will be compensated, their incentive to do something to reduce their annoyance disappears, resulting in too many homes located near airports.

FIGURE 1
The Optimal Externality Price

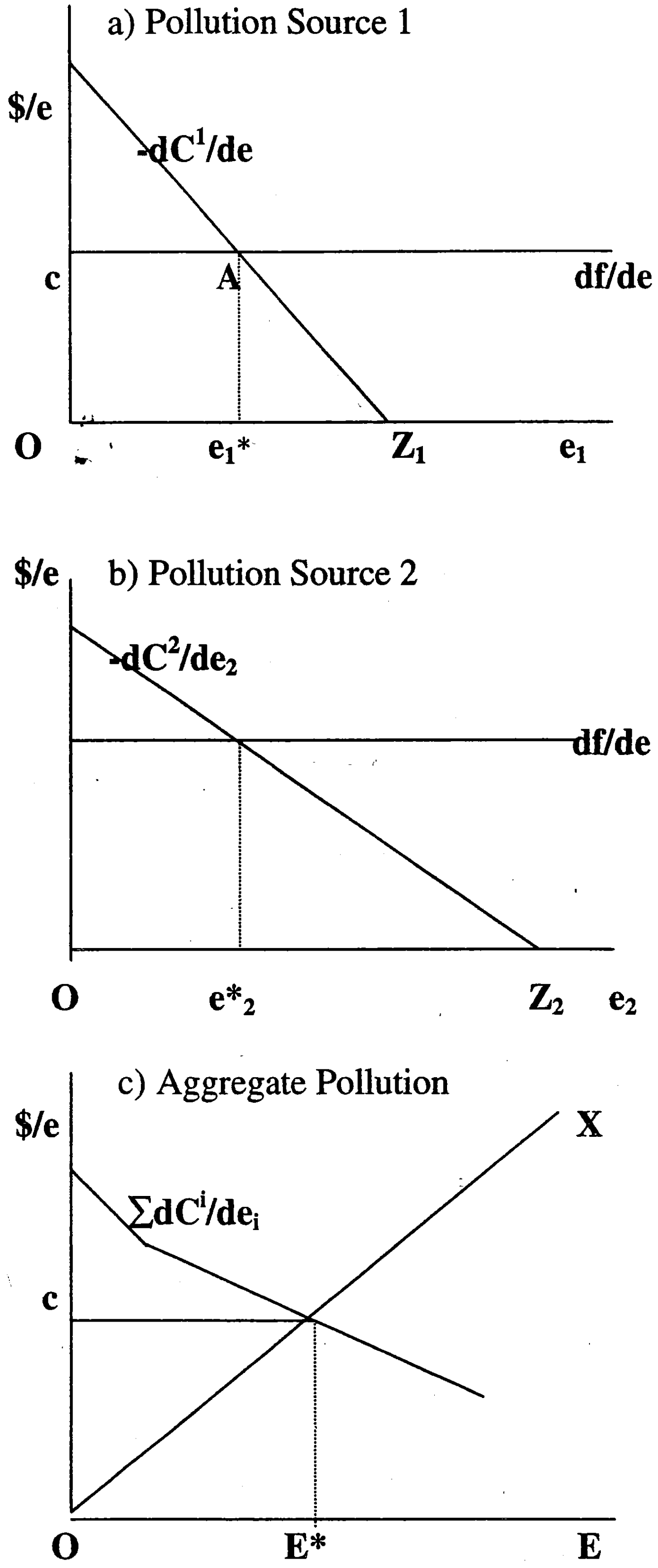
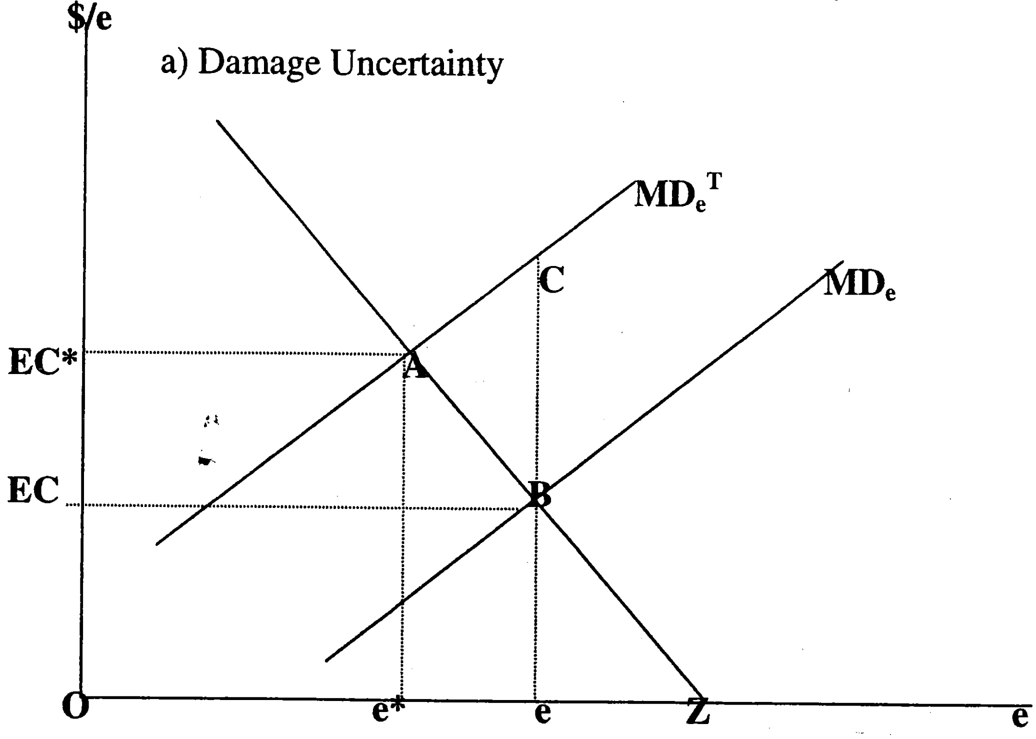
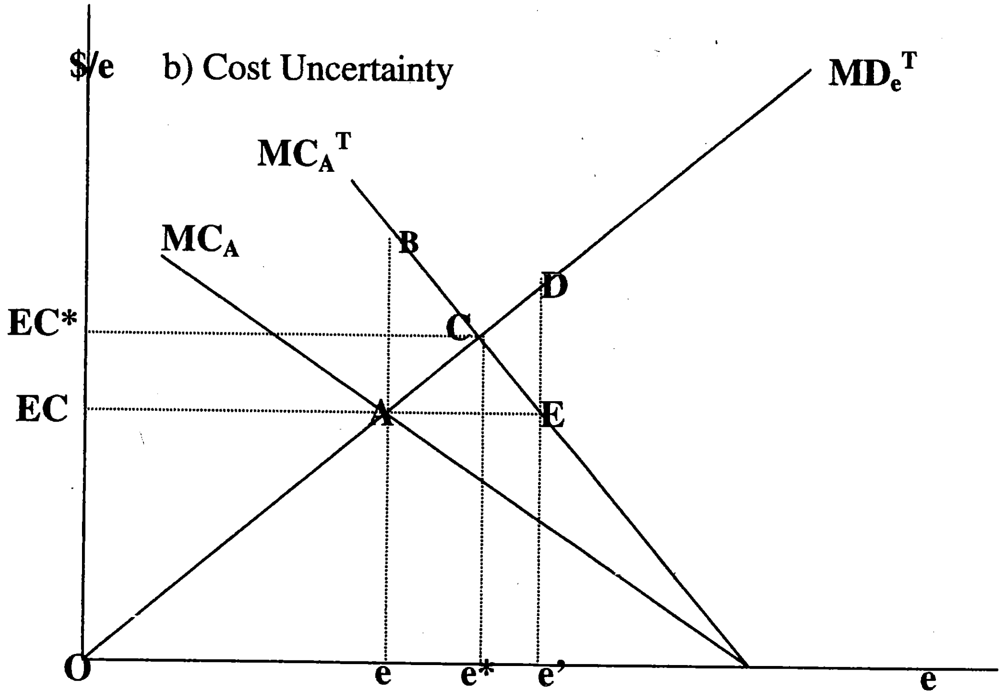


FIGURE 2
Prices Versus Quantities with Uncertainty



a) Damage Uncertainty



b) Cost Uncertainty

FIGURE 3
The Impact of Externality Pricing on a Monopoly

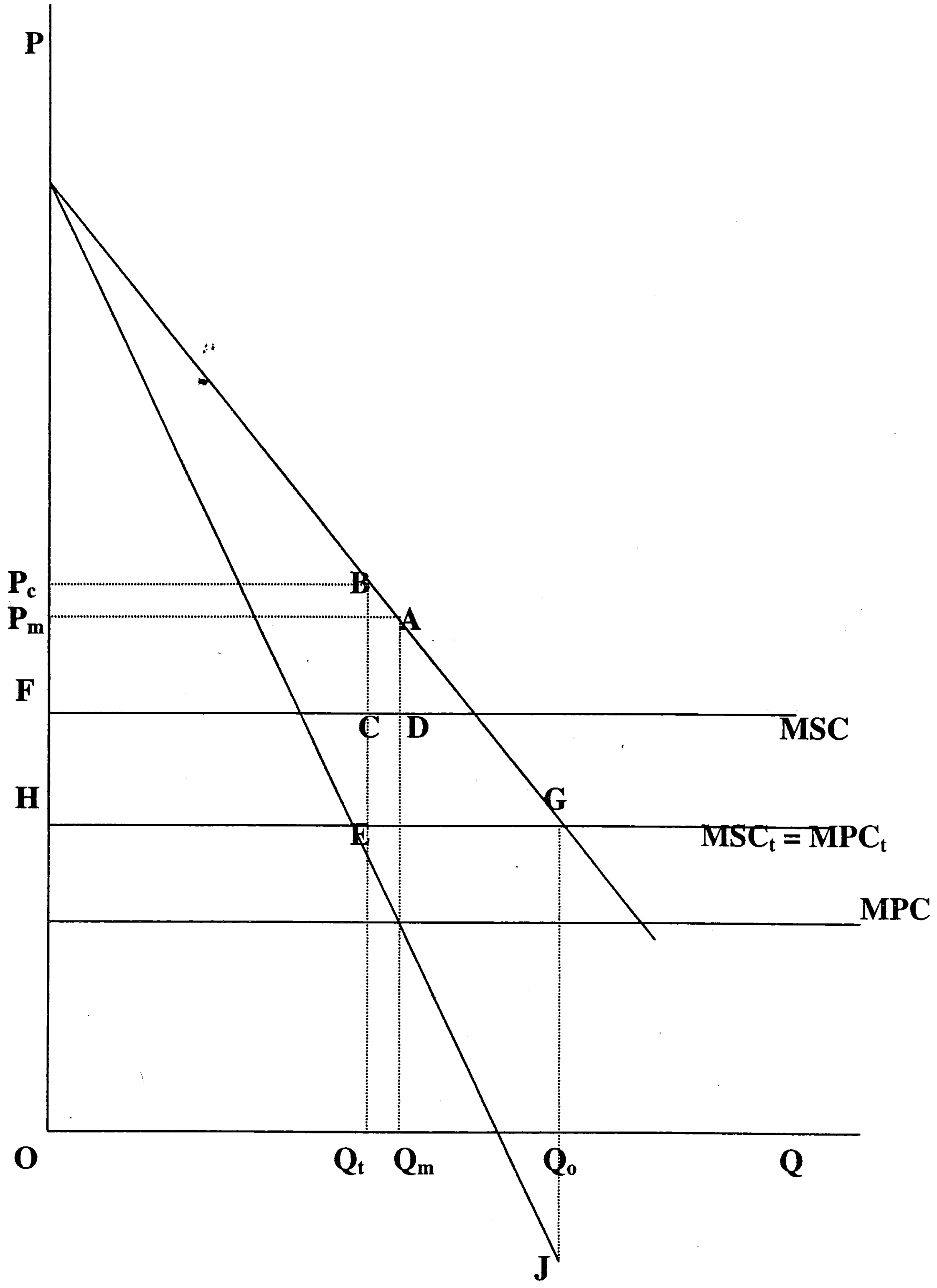
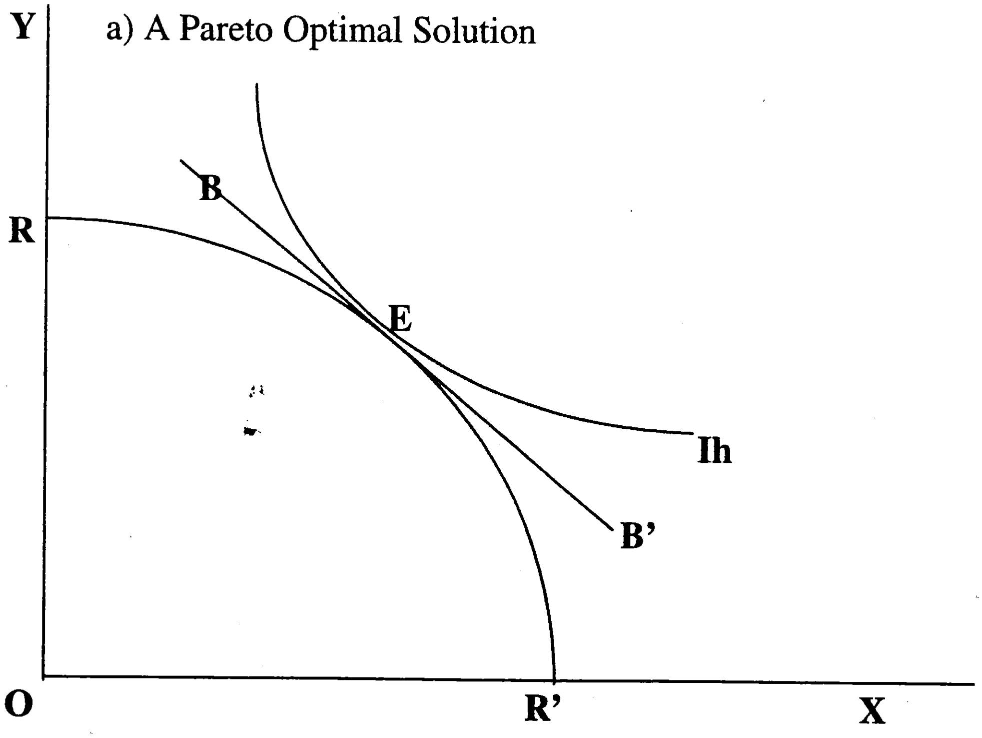


FIGURE 4
Nonconvexities and Pareto Optimality


a) A Pareto Optimal Solution

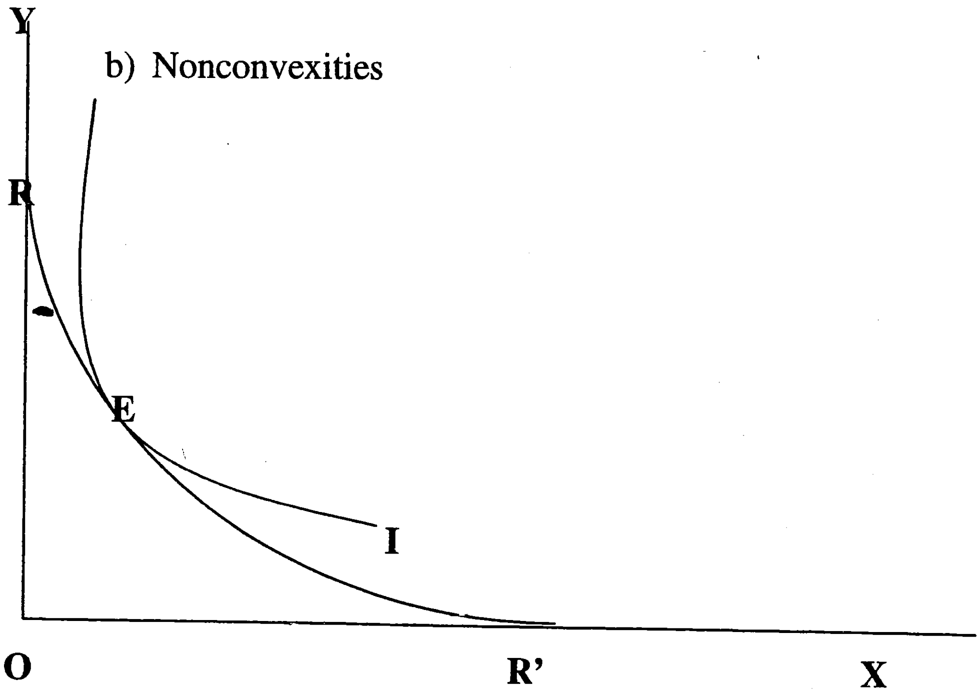

b) Nonconvexities

FIGURE 4
Nonconvexities and Pareto Optimality

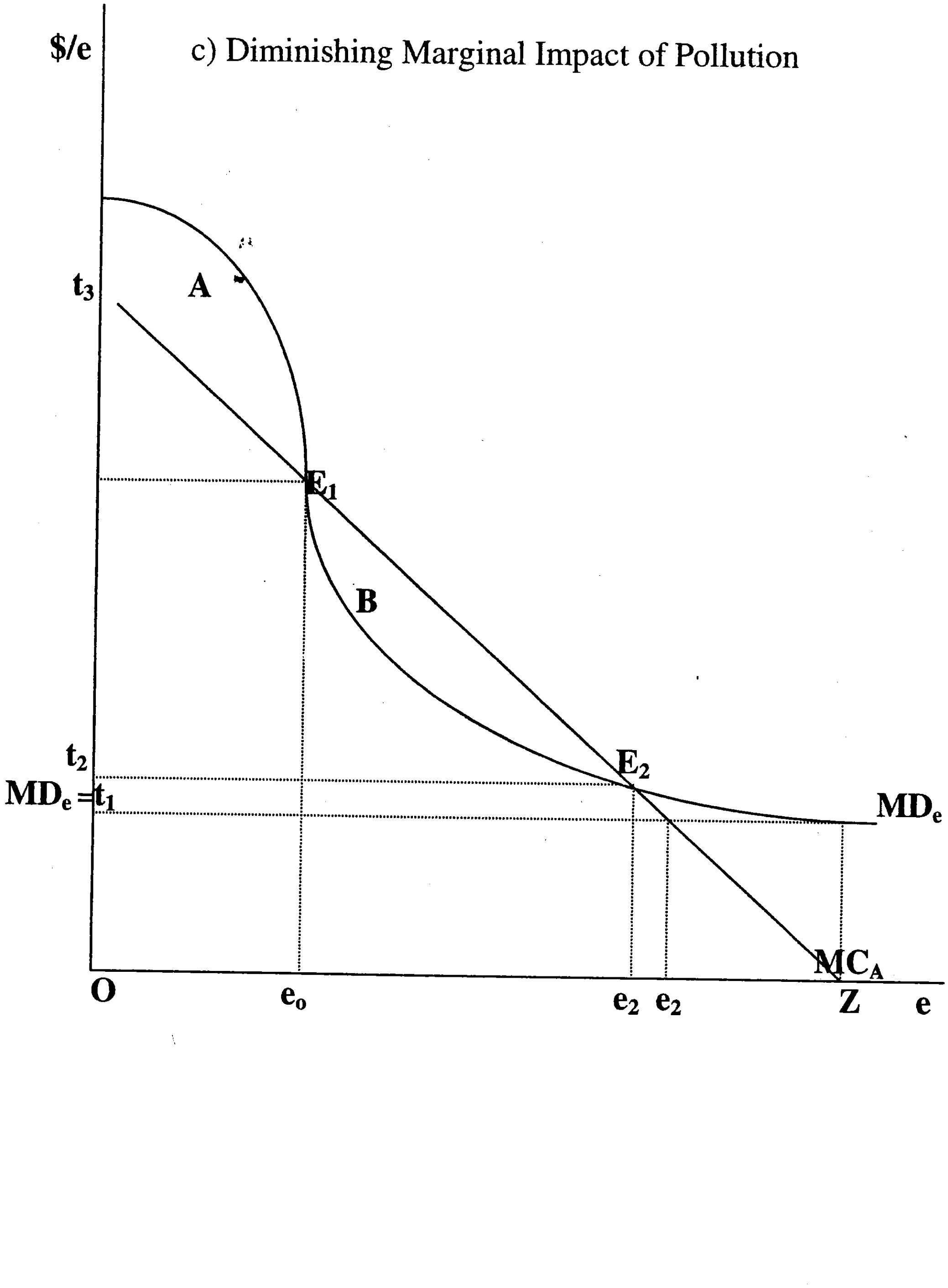


FIGURE 5
Cost Effectiveness of Externality Prices

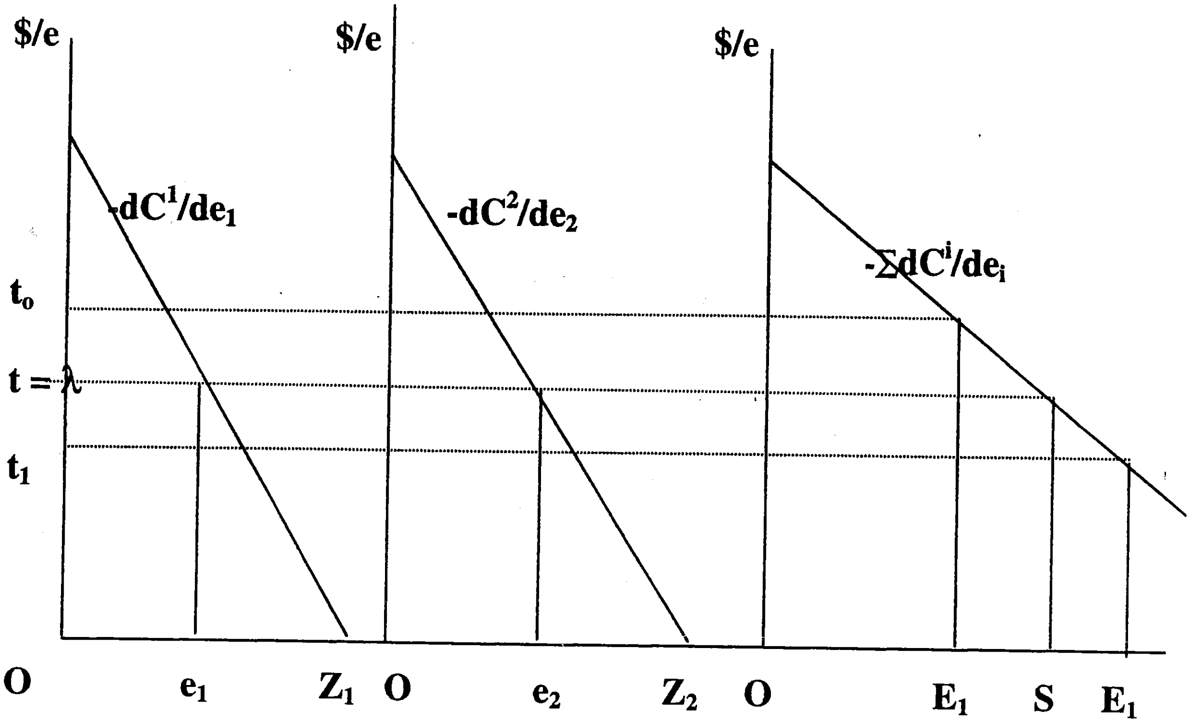


FIGURE 6
Dynamic Efficiency with Standards and Charges

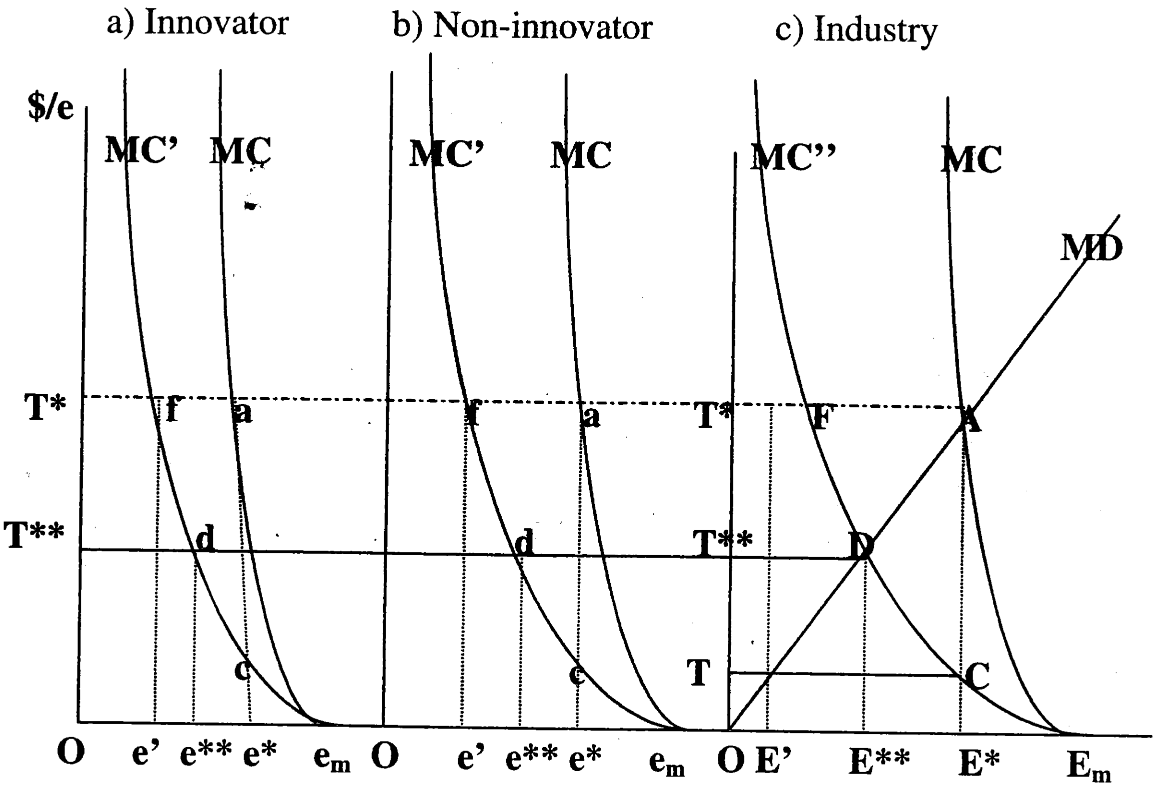
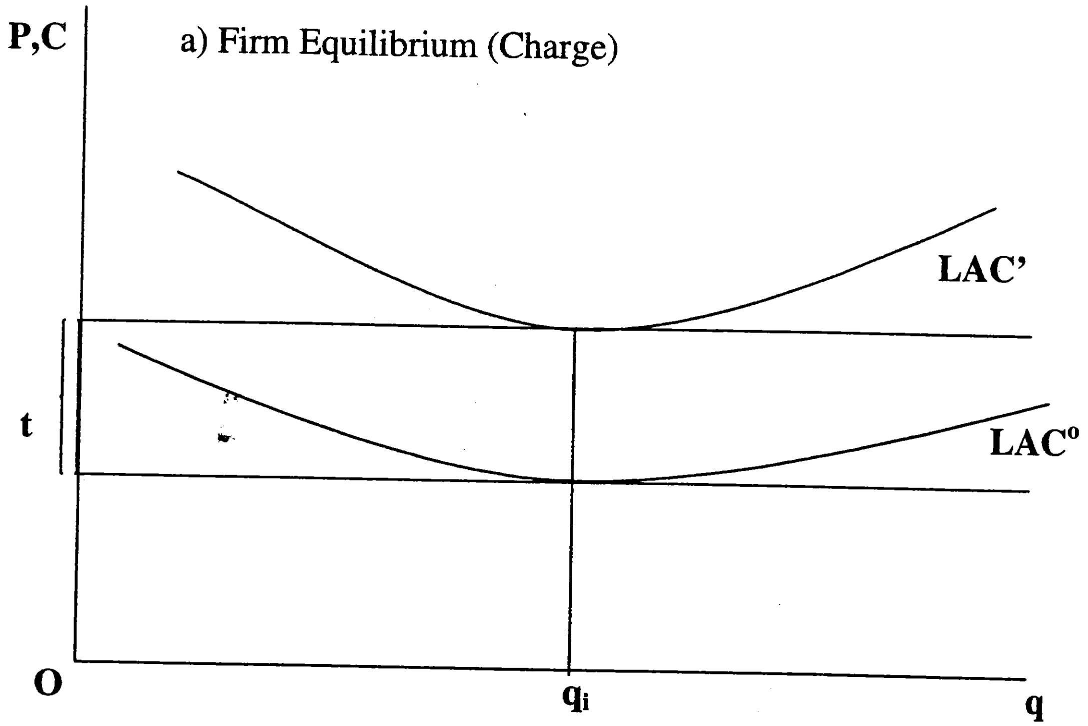


FIGURE 7
Distributional Impact of Standards and Charges

a) Firm Equilibrium (Charge)



b) Industry Equilibrium (Standard)

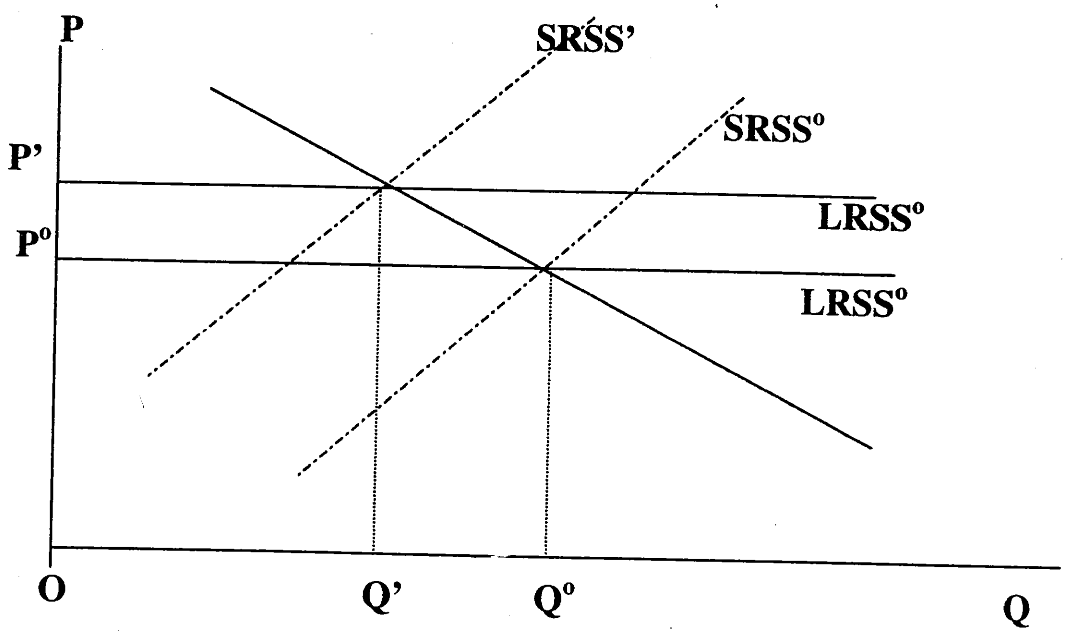


FIGURE 7
Distributional Impact of Standards and Charges

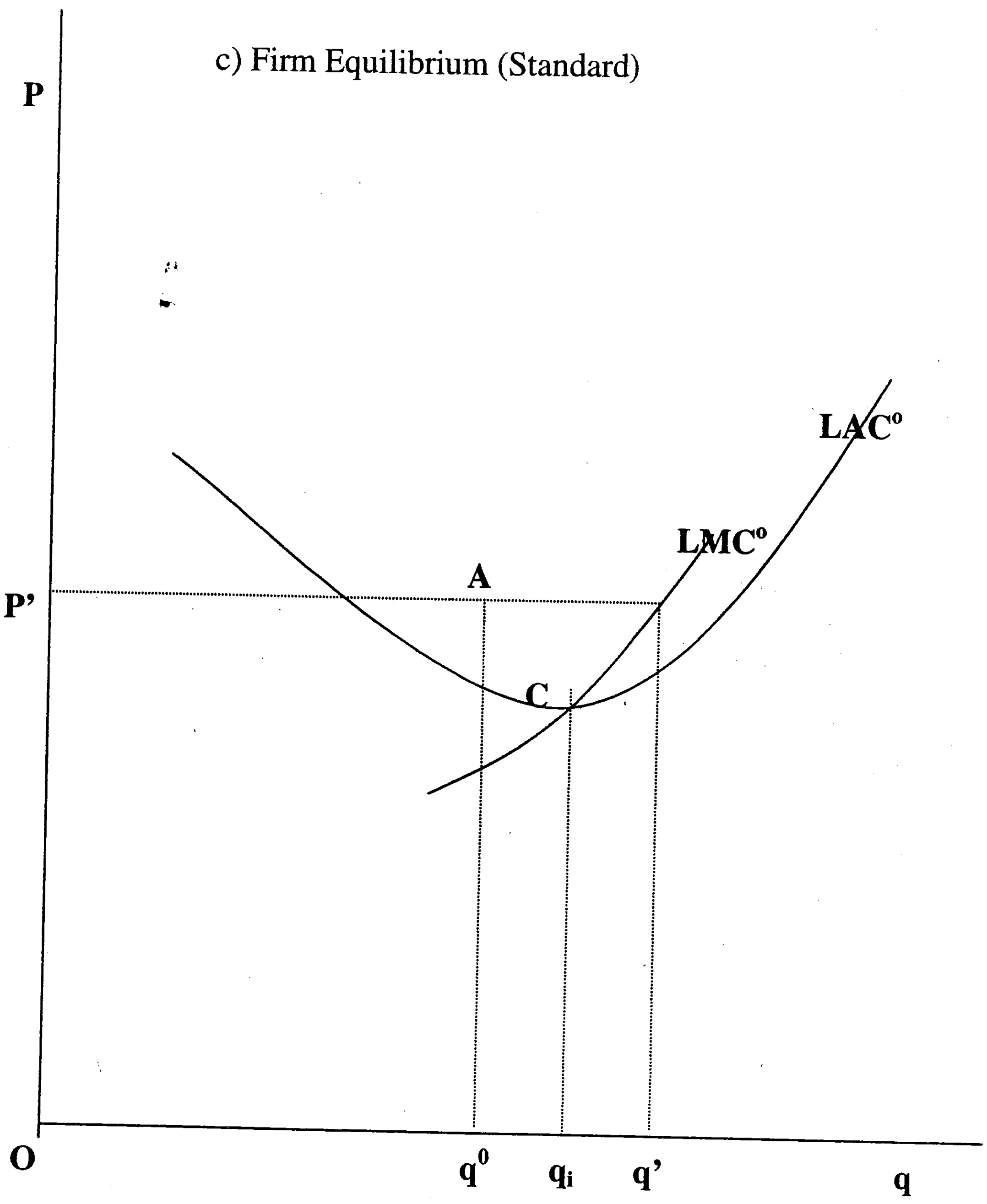
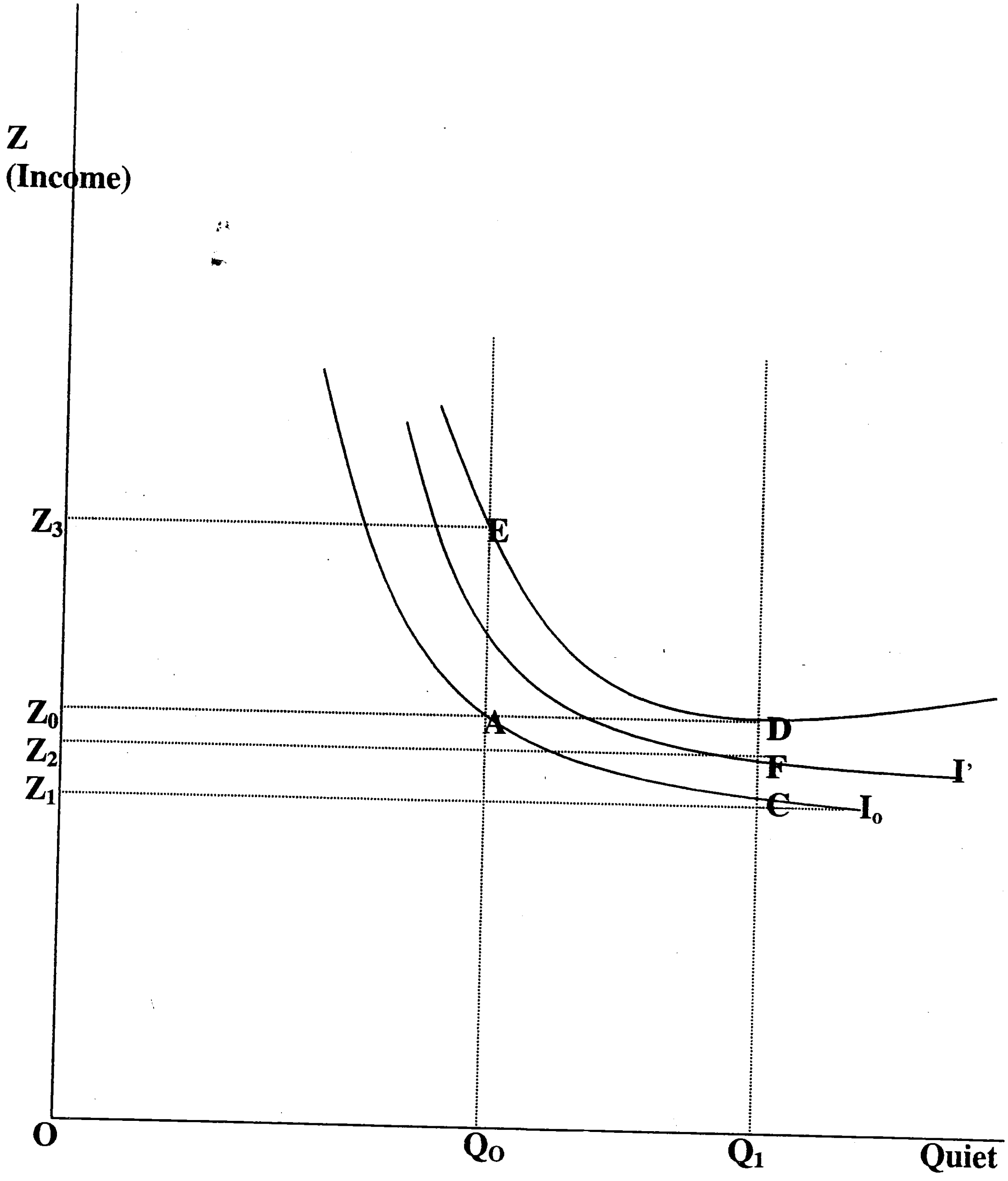


FIGURE 8
The Impact of Compensation for a Victim of Noise Pollution



Bibliography

Books

Anderson, F. R., A. V. Kneese, P.D. Reed, S.Taylor and R.B Stevenson (1977) *Environmental Improvement through Economic Incentives*, (Baltimore: The John Hopkins Press)

Baumol, W.J. and W.E. Oates (1979) *Economics, Environmental Policy and the Quality of Life,* Englewood Cliff, (New Jersey: Prentice-Hall, Inc.)

Baumol, W.J. and W. E. Oates (1988) *The Theory of Environmental Policy.* (Cambridge, Mass: Cambridge University Press)

Burrows, P. (1980) *The Economic Theory of Pollution Control.* (Cambridge, Mass: The MIT Press)

Chant, J. F., D.G. McFetridge and D.A. Smith (1990) “The Economics of the Conserver Society,” *Economics and the Environment: A reconciliation*, (Vancouver: The Fraser Instititute)

Crandall, R. W., H. K. Gruenspecht, T.E. Keeler and L.B. Lave (1986) *Regulating the Automobile*, (Washington, D.C.: The Brookings Institution.)

Dales, J.H. (1968) *Pollution, Property and Prices,* (Toronto: University of Toronto Press)

Dewees, D. N. (1974) *Economics and Public Policy: The Automotive Pollution Case*, (Cambridge, Mass.: The MIT Press).

Dewees, D. N. (1980) Evaluation of Policies for Regulatory Environmental Pollution, Economic Council of Canada, Regulation Reference, Working Paper #4

Elliot, R. and J. Seagraves (1972) “The Effects of Sewer Surcharges on the Level of Industrial Wastes and the Use of Water by Industry,” *Water Resources Research Institute* (Report #70)

Felske, B.E. and Associates Ltd. (1981) “Sulphur Dioxide Regulation and the Canadian Non-Ferrous Metals Industry,” *Economic Council of Canada*, (Technical Report #3)

Fisher, A.C. (1981) *Resource and Environmental Economics*, (Cambridge, Mass.: Cambridge University Press)

Gillen, D. and T. Levesque (1990) *The Management of Airport Noise*. For Transportation Development Centre Policy and Coordination Group, Transport Canada

Harrison, D. Jr. (1983) "The Regulation of Aircraft Noise, in Schelling, T.C., ed. *Incentives for Environmental Protection*, (Cambridge, Mass.: The MIT Press)

Kneese, A. V. (1977) *Economics and the Environment* (New York: Penguin Books)

Nelson, J. P. (1978) *Economic Analysis of Transportation Noise Abatement*, (Cambridge, Mass.: Ballinger Publishing Co.)

OECD (1989) *Economic Instruments of Environmental Protection*, (Paris: Organisation for Economic Co-operation and Development)

Quinn, T. H. (1983) "Distributive Consequences and Political Concerns: On the Design of Feasible Market Mechanisms for Environmental Control," in Joeres, E.F. and M.H. Davids, eds. *Buying a Better Environment: Cost Effective Regulation through Permit Trading*. (Madison, Wisc.: The University of Wisconsin Press)

Russell, C.S., W. Harrington and W.J. Vaughan (1986) *Enforcing Pollution Control Laws*, (Washington, D.C.: Resources for the Future)

Sims, W. A. (1992) *Externality Pricing*, (Toronto: Minister of Supply and Services Canada)

Starkie, D. N. M. and D. M. Johnson (1975) *The Economic Value of Peace and Quiet*, (Lexington, Mass.: Lexington Books)

Tietenberg, T. H. (1988) *Environmental and Natural Resources Economics*, (Glenview, Illinois: Scott, Foresman and Co.)

Journals

Adar, Z. and J. M. Griffin (1976) "Uncertainty and the Choice of Pollution Instruments," *Journal of Environmental Economics and Management* 3, 173-188.

Amacher, G. S. and A. S. Malik (1998) "Instrument of Choice when Regulators and Firms Bargain," *Journal of Environmental Economics and Management* 35, 225-241.

Asch, P. and J.J. Seneca (1978) "Some evidence on the Distribution of Air Quality," *Land Economics* 54, 278-97.

Baumol, W.J. and W. E. Oates (1971) "The Use of Standards and Prices for Protection of the Environment." *Swedish Journal of Economics* 73, 42-54.

Benford, F.A. (1998) "On the dynamics of the Regulation: Incentive Compatible Regulation of a Persistent Pollutant," *Journal of Environmental Economics and Management* 36, 1-25

Brown, G. M and R. W. Johnson (1984) "Pollution Control by Effluent Charges: It Works in the Federal Republic of Germany, Why not in the U.S." *Natural Resources Journal 24*, 929-66.

Buchanan, J and G. Tollock (1975) "Polluters Profits and Political Response: Direct Controls vs. Taxes," *American Economic Review* 65, 139-47.

Button, K. (1990) "Environmental Externalities and Transport Policy." *Oxford Review of Economic Policy* 6, 2.

Coase, R. (1960) "The Problem of Social Cost." *Journal of Law and Econo*mics 3, 1-44.

Dewees, D.N. (1976) "Travel Cost, Transit and Control of Urban Motoring." *Public Policy* 24, 59-79.

Dewees, D. N (1983) "Instrument Choice in Environmental Policy," Economic Inquiry 21, 53-71.

Ethridge, D (1972) "User Charges as a Means for Pollution Control: The Case of Sewer Surcharges," *The Bell Journal of Economics* 3, 346-54.

Fullerton, D., S. P. McDermott, and J. P. Caulkins (1997) "Sulfur Dioxide Compliance of a Regulated Utility," *Journal of Environmental Economics and Management* 34, 32-35.

Gruenspecht, H. K. (1982) "Differentiated Regulation: The Case of Auto Emission Standards," *American Economic Association Papers and Proceedings* 72, 328-31

Hagem, C. and H. Westkog (1998) "The Design of a Dynamic Tradeable Quota System under Market Imperfections," *Journal of Environmental Economics and Management* 36, 81-107.

Horan, R.D., J.S. Shortle, and D. G. Abler (1998) "Ambient Taxes when Polluters have Multiple choices," *Journal of Environmental Economics and Management* 36, 186-199.

Joskow, P. L., R. Schmalensee, and E. M. Bailey (1998) "The Market for Sulfur Dioxide Emissions," *The American Economic Review* 88, 669-685.

Knanna, M. and Damon, L. (1999) "EPA's Voluntary 35/50 Program: Impact on Toxic Releases and Economic Performance of Firms" *Journal of Environmental Economics and Management* 37, 1-25.

Magat, W. A. (1978) "Pollution Control and Technical Advance: A Dynamic Model of the Firm," *Journal of Environmental Economics and Management* 5, 1-25.

Milliman, S. R. and R. Prince (1989) "Firm Incentive to Promote Technological Change in Pollution Control," *Journal of Environmental Economics and Management* 17, 247-65.

Roberts, M.J. (1970) "River Basin Authorities: A National Solution to Water Pollution," *Harvard Law Review* 83, 1527-56.

Sims, W. A. (1979) "The Response of Firms to Pollution Charges." *Canadian Journal of Economics* 12, 57-74.

Stigler, G. J. (1971) "The Theory of Economic Regulation." *The Bell Journal of Economics and Management* 2, 3-21.

Tietenberg, T. H. (1990) "Economic Instruments for Environmental Regulation," Oxford *Review of Economic Policy* 6, 1, 17-33.

Victor, P.A. and T. N. Burrell (1984) "Losses from Effluent Taxes and Quotas Under Uncertainty," *Journal of Environmental Economics and Management* 11, 310-26.