1. Introduction

1.1 Introduction

In recent years the average levels of salt measured in the Upper Hunter River, New South Wales, has increased. The salinity threshold of 700 EC (420 mg/L) (recommended by the Environmental Protection Agency - EPA), is regularly exceeded, causing widespread concern among water users (for example, EPA 1994a; DWR 1994). A natural "base load" of salt occurs due to the surface and groundwater drainage of a catchment being formed largely of saline sedimentary rocks. Coal mining contributes to the exposure and weathering of these rocks, thus increasing the amount of salt that enters the river. With mining set to expand in the Upper Hunter Valley, the discharge of saline minewater to the river represents an important emission control problem.

Pollution taxes (also termed effluent charges) and transferable discharge permits represent the two major alternative policy tools that are being considered for controlling pollution in streams. Effluent charges have been used in some European countries, with varying degrees of success. In general, taxes have been set too low to achieve the desired goal (Howe, 1994), and tax rates have been fixed for long periods of time, thus ignoring the high variability in stream assimilative capacity. The emphasis in this study is on the use of price incentives, rather than direct regulation, to achieve the environmental standard.

The capacity of the Hunter River to assimilate salt discharges, without exceeding the recommended environmental standard, depends on the streamflow and natural salinity at any time, and both these factors are highly variable. Salt discharge policies, therefore, must account for such variability in order to maintain salinity below the level of the standard.

In the Hunter River system various minewater discharge policies have evolved, usually involving some form of short term license issued by the EPA upon request by the mines. Increasing pressure on the ability of the river to assimilate the salt discharges has led the

EPA to investigate more sophisticated methods for controlling these discharges. Load based pollution taxes represented an attractive policy tool, because they have the additional advantage of providing a source of income for the regulating authority. Transferable discharge permits, and various methods of 'staged discharge', designed to encourage discharge to coincide with periods of high assimilative capacity, were also investigated. Subsequent to beginning this study, transferable discharge permits were chosen by the EPA as the preferred policy tool. Despite the change in direction of the regulating authorities this study is a significant contribution to the information available for the use of pollution taxes in highly stochastic and dynamic systems like the Hunter River. It also provides significant insights into transferable discharge permit systems.

This dissertation presents a stochastic dynamic simulation model which provides insight into the information requirements needed for efficient setting of a pollution control charge. The model accounts for the stochastic nature of river flows, natural salinity and the correlation between these variables. It is shown that the level of the salt tax must be constantly adjusted in response to the rivers' assimilative capacity and the marginal cost of water treatment. Implications in terms of administrative requirements and the suitability of a charge for controlling salt discharge in the Upper Hunter Valley are discussed.

1.2 Scope of work, aims and objectives

The purpose of this work is to explore the possible effects of various tax policies on a range of variables associated with salt discharge from mines in the Hunter River system. Since the analysis of this dissertation is exploratory in nature, no formal hypotheses are stated. The complex interactions caused by the dynamic and stochastic nature of river flows and salinity make it impossible to advance simple hypotheses to be tested. The dissertation proceeds by developing a simulation model and using actual data to explore the effects of the different tax policies under a range of assumptions.

Specific research objectives which serve to guide this research are:

i) To assess the relative merits of load based, variable rate taxes versus flat rate taxes in utilising the assimilative capacity of the river to achieve a set standard of salinity at low cost.

ii) To assess the feasibility of alternative tax regimes paying particular attention to information requirements

iii) To draw implications arising from the study with respect to the design and operation of variable tax rate policies and transferable discharge permit schemes.

All three objectives are investigated using a dynamic stochastic simulation model. The first objective is examined using the amount of tax collected and costs of treatment, together with the frequency of meeting the environmental standard. The second objective is achieved through the process of designing an operational model, and the third objective is met in the policy implications chapter of this document.

1.3 Research method

The simulation model used in this project was developed in an attempt to model the characteristics of the highly stochastic and dynamic system of the Hunter River. The model uses actual streamflow data and synthesised conductivity data to predict the assimilative capacity of the river. The proposed tax regimes are explored for their informational requirements, relative treatment and tax costs as well as for the reliability of meeting the environmental standard.

1.4 Outline of dissertation

Chapter 2 comprises a review of literature on the theory and application of pollution taxes and transferable discharge permits. Chapter 3 reports on the specific nature of salinity in the Hunter River system. A tax policy is formulated and modelled in Chapter 4 and data used to calibrate the model, its sources and quality are presented and reviewed in Chapter 5. Chapter 6 presents the results from the model, sensitivity analysis and general discussion of the results. The final chapter discusses policy implications and conclusions that can be drawn from this work.

2. Literature review: Policy tools to control pollution

2.1 Introduction

The purpose of this chapter is to describe some of the policy tools available to governments to control pollution. In order to understand the formulation of the tax policy presented in Chapter 4 of this study, knowledge of the theory and economic rationale supporting cost-effective policy tools is essential. For this reason, much of the work presented in this review covers the theoretical base for the use of pollution taxes and transferable discharge permits.

The emphasis of this study is on the formulation of a tax policy to control the discharge of salt from mines to the Hunter River. Transferable discharge permits are also examined in reasonable detail for the following reasons. First, pollution taxes and discharge permits both represent ways of achieving an environmental standard using cost-minimising methods. Second, this study in no way wishes to portray taxes as the best solution to pollution in the Hunter River, but instead attempts to investigate the advantages and disadvantages of and alternatives to the use of efficiently set pollution taxes. Finally, and perhaps most importantly, is the current situation in the Hunter River itself. Subsequent to beginning this study, a system of transferable discharge permits was implemented in the Hunter River and its tributaries.

The sections that follow review the literature on the theory of economic instruments designed to achieve environmental standards. The advantages and disadvantages of each policy over the more traditional direct controls used by governments are highlighted. Examples of the use of these policy tools for different water pollution problems are also reported, and the strengths and limitations of implementing each instrument are examined. The chapter begins with some definitions of economic pollution and optimal pollution.

2.2 Economic and optimal levels of pollution

The notion that pollution can exist at an optimal level is central to pollution control policies such as pollution taxes and transferable discharge permits. From an economists point of view, it is not enough to have a purely physical pollutant in the environment. For economic pollution to occur, the waste product (pollutant) must cause some effect on a third party who remains uncompensated - a negative externality. If the third party receives appropriate levels of compensation to negate the effect of the pollution, then the pollution is said to be internalised and can no longer be viewed as pollution in an economic sense. Even in the absence of economic pollution, the pollution remains in a physical or biological context. Moreover, not only is it possible to have physical pollution and no economic pollution, but it is also possible to have economic pollution which is optimal. That is, economic pollution for which the costs of either compensating third parties or physically removing the pollutant from the environment exceed the benefits of doing so. These ideas are discussed in detail in the following sections.

2.2.1 Deriving the optimal level of pollution

The optimal level of pollution is defined as the level of pollution which occurs when the marginal benefits from reducing pollution are equal to the marginal cost of reducing the pollution. Figure 2.1 illustrates this derivation graphically, using a hypothetical marginal net social benefit (MNSB) curve and a hypothetical marginal abatement cost curve (MAC). The point of intersection of the two curves, is the optimal level of pollution.

The social benefit curve includes all benefits which would be gained by society for each unit of pollution removed from the environment. These benefits may include the increased amenity value of the water resource and increases in the recreational activities due to the reduced pollution. It may also include any preservation values that arise from reducing pollution of the resource now and preserving it for future use, as well as the benefits that arise from preserving animal and plant species which would have been unable to survive in the presence of pollution. Many of these benefits, however, are not directly priced in the market, making it very difficult to express the marginal net social benefit to society from reducing pollution. A range of techniques which attempt to value these benefits and costs to society include contingent valuation, hedonic pricing,

travel cost approach and direct and indirect valuation. For a brief introduction to all of these techniques, see Pearce and Turner (1990, Ch.10).

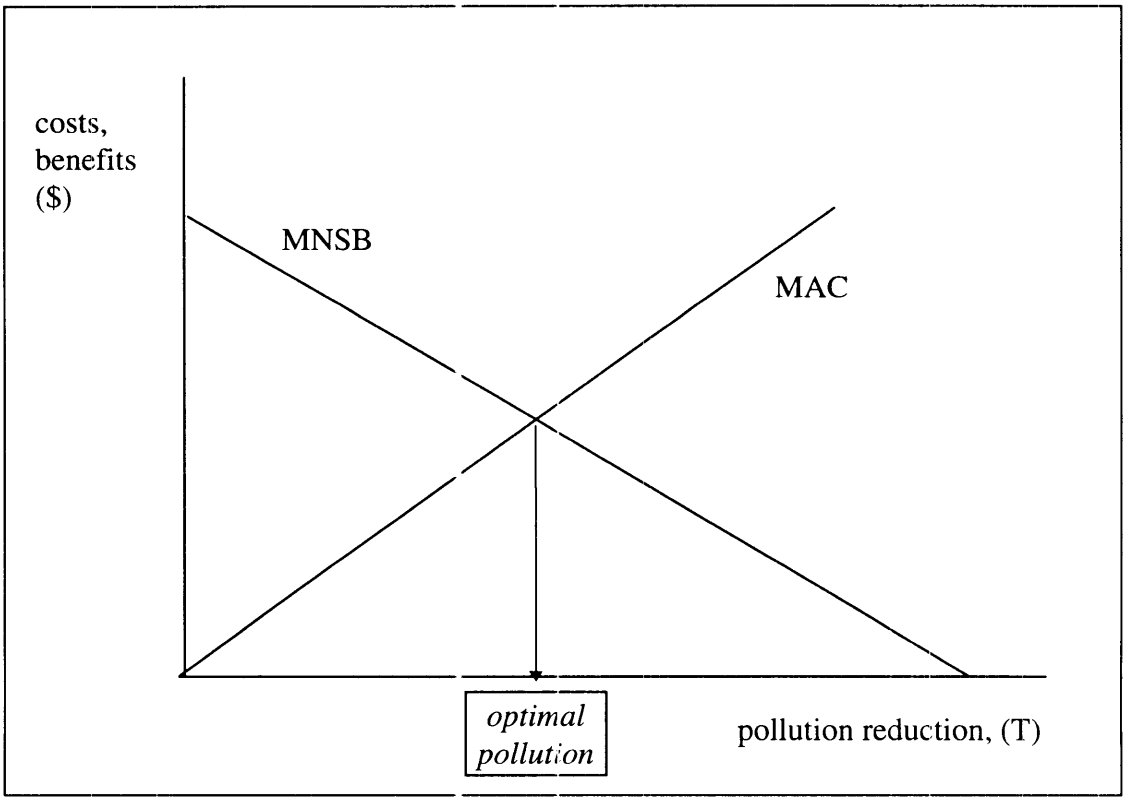


Figure 2.1 Optimal pollution

The marginal net social benefit curve may not be linear as shown in Figure 2.1. However, it is generally accepted that it would be downward sloping, since the first units of pollution removed from the environment would provide high benefits, while removing progressively more pollution would provide relatively fewer benefits as the concentration of pollutants in the environment is reduced. Similarly, the marginal abatement cost curve may not be linear. It could be exponential and asymptotic, or it could be stepped. The argument that the marginal cost of abatement would be positively sloped is based on the fact that the first units of pollution are the cheapest to remove, and as the water (or air) becomes cleaner, the cost of removing further units of the pollutant increase.

Once it is established that economic pollution is occurring at a level which is greater than the optimal level, it is clear that efficient allocation of resources is not occurring and some form of regulatory action is generally justified. Section 2.3 discusses different policy tools used by governments.

2.3 Policy tools for the control of pollution

Economists subscribe to the general belief that markets provide one of the best mechanisms available for the efficient allocation of resources. In a number of instances, however, markets perform less than satisfactorily in allocating resources, and it is for this reason that some form of intervention (usually by governments) is justified. In the case of pollution, it is evident that markets fail to allocate the use of the environment (eg water or air) as a waste sink. The fact that a polluter, incurs no cost for using the environment as a waste disposal service, means that there is little incentive for the polluter to find an alternative method of disposal. Where this waste affects third parties, externalities occur and economic pollution results. The presence of externalities indicates that the ability of the markets to efficiently allocate resources is impaired.

Broadly speaking, there are three types of policy tools available to governments to influence economic pollution. Direct controls such as a standard and penalty approach, price control such as pollution charges (taxes) or subsidies, and quantity controls such as marketable permits. Direct controls have traditionally been the response of governments to pollution control. These policies have merits where strict adherence to minimum standards are necessary, such as for highly toxic pollutants however, for the majority of pollution problems, direct controls are a costly means of achieving an environmental standard. Pollution charges or taxes which are set at an efficient level, can provide a cost-minimising means of achieving a given set of standards (Baumol and Oates, 1988). They do this by attempting to internalise the external costs associated with economic pollution. Transferable discharge permits are credited with the same cost-minimising properties (for example see Hahn and Hester 1987; Hahn and Noll 1990), except that instead of addressing the externality problem, as is the case for taxes, market failure is addressed through clear definition of property rights. Permits which limit pollution to the level of the environmental objective are offered for sale to the

highest bidders. The total level of pollutant entering the system is regulated through the permits, but cost-effectiveness is achieved by allowing the transfer of these permits amongst dischargers (Tietenberg 1990; Baumol and Oates 1988).

2.3.1 Direct controls

Governments have traditionally preferred to implement direct regulatory controls on polluters. Direct controls most often take one of two forms, requiring that nominated pollution-reducing technology be adopted by the discharging firm, or setting a standard enforced by penalties. Neither of these regulations takes account of the marginal costs of abatement of discharging firms. Instead, the first dictates that specific abatement equipment must be utilised, whether or not it is an efficient solution for the dischargers involved. Given that the dischargers are unlikely to have the same abatement cost curves, (due to different size plants offering different economies of scale and different resource bases providing different comparative advantages) there is the likelihood that a great many dischargers, if not all, will be forced to adopt technology which is not optimal for their particular plant size and circumstance.

Direct controls which force polluters to discharge a stated level of pollution to ensure that the environmental standard is met, are usually enforced by a strict penalty. Pearce and Turner (1990) and Baumol and Oates (1988) term this type of policy a standard and penalty approach. Obviously, compliance with the standard will depend on the perceived probability of being caught, together with the probability of prosecution if a fine is not paid, and the size of the penalty. The penalty must be large enough for the firm not to be able to write off the fine as a working cost, if it is to be effective as a deterrent from polluting. Under this system, the firms are totally at the mercy of the government or regulating authority, who can change the rules at any time. If, for example, a firm wishes to enter the industry then the allowable discharge faced by each polluter would need to be reduced to allow for this. Because there are no property rights associated with the right to discharge, the existing dischargers are not entitled to any compensation for the forced reduction in discharge.

Direct controls send distorted price signals to dischargers, which can result in firms using inefficient methods of pollution abatement and adopting suboptimal levels of pollution reduction. By not allowing dischargers to identify their cost-minimising mix of pollution abatement and pollution discharge, direct controls do not achieve efficient solutions. Taxes and transferable discharge permits are alternative policies, which allow greater flexibility for individual dischargers to seek the cost-minimising mix of pollution treatment and discharge tailored to the specific needs of the firm. They are described below.

2.3.2 Pigovian taxes and optimal pollution

Pigovian taxes are a method of redressing the externalities which discharging firms impose on others by internalising the cost of pollution. A tax is applied to every unit of waste discharged to the environment. The optimal rate of a Pigovian tax is equal to the external cost (the cost of damage) of pollution at the optimal level of pollution. Figure 2.2 shows the optimal Pigovian tax rate.

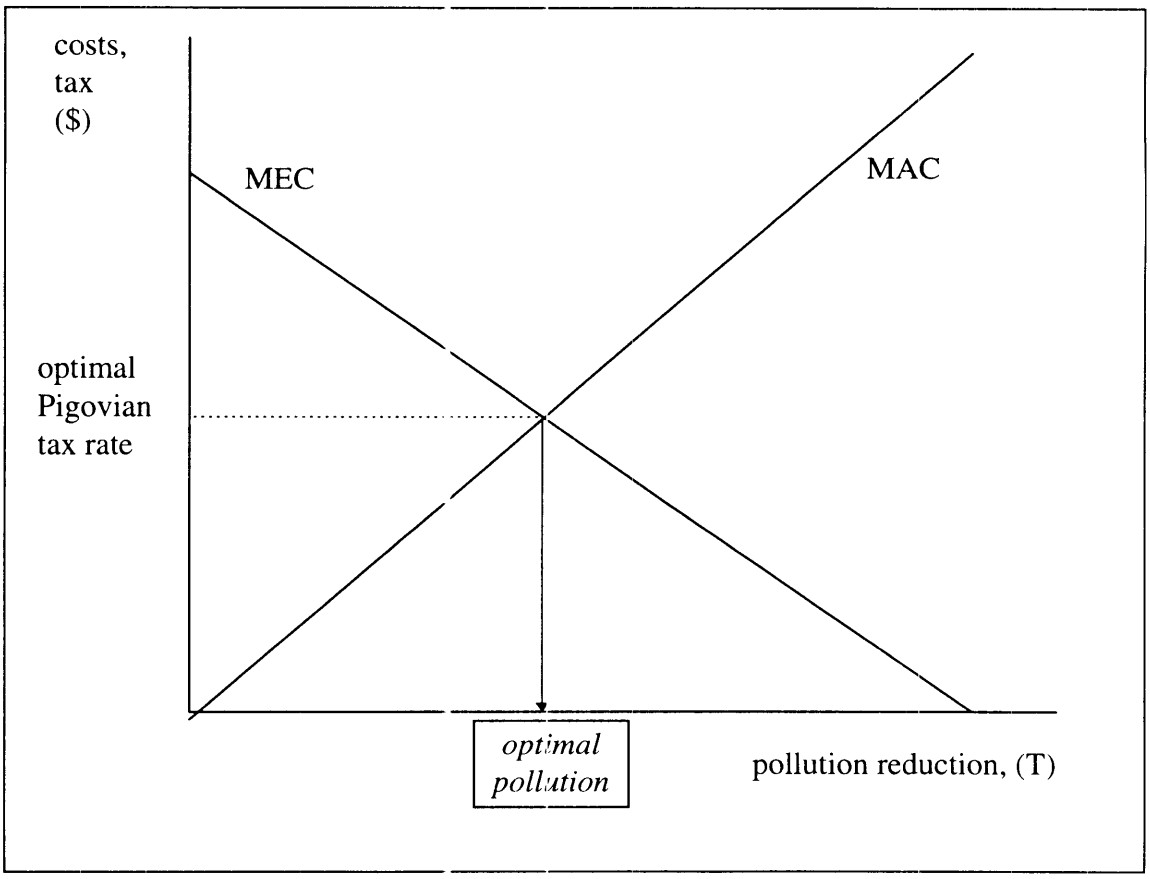


Figure 2.2 The optimal Pigovian tax rate

In order to set a Pigovian tax it is necessary for the regulator to know both the marginal cost of damage (marginal external cost) caused by the pollution, and the marginal cost of abatement. Both these functions need to be known so that the optimal level of pollution can be identified, and the external costs which occur at this level of pollution can be calculated, providing the optimal tax rate.

Pigovian taxes, however, have not been used as policy tools for two main reasons. First, they require knowledge of at least part of the marginal benefit (or damage) function of pollution, and as noted earlier, this is extremely difficult to measure. Second, they assume perfect competition in the market (see Pearce and Turner 1990; Baumol and Oates 1988), which is an unrealistic assumption.

In order to use the essence of Pigovian taxes in a policy to address pollution problems, more realistic information requirements are necessary. Effluent charges (or pollution taxes) achieve this by sacrificing the optimal level of pollution as the policy objective. Instead, an environmental standard is chosen on the basis of some appropriate criteria, and the tax is then set equal to the MAC at the abatement level required to achieve this standard.

2.4 The environmental standard

Choosing the appropriate level of the environmental standard is beyond the scope of this study, but it could cover any number of methods. For example, it might be based on health reasons or a general level of pollutant which can be tolerated by the majority of water users. This then becomes the environmental standard which may, or may not, correspond to the optimal level of pollution. Achieving this standard at minimum cost to society is the objective of cost-effective policies, such as effluent charges (pollution taxes) and transferable discharge permits.

2.4.1 Setting a pollution tax or effluent charge

The essence of Pigovian taxes is seen in effluent charges and pollution taxes. The pollution tax forces dischargers to internalise the costs of pollution associated with polluting to the level of the environmental standard. As for the Pigovian tax, pollution taxes require the regulator to have knowledge of the marginal abatement cost curve that

the industry is likely to face. In contrast to the Pigovian tax, where the optimal level of pollution is calculated, effluent charges are set equal to the marginal cost of abatement needed to achieve the environmental standard, this is shown in Figure 2.3

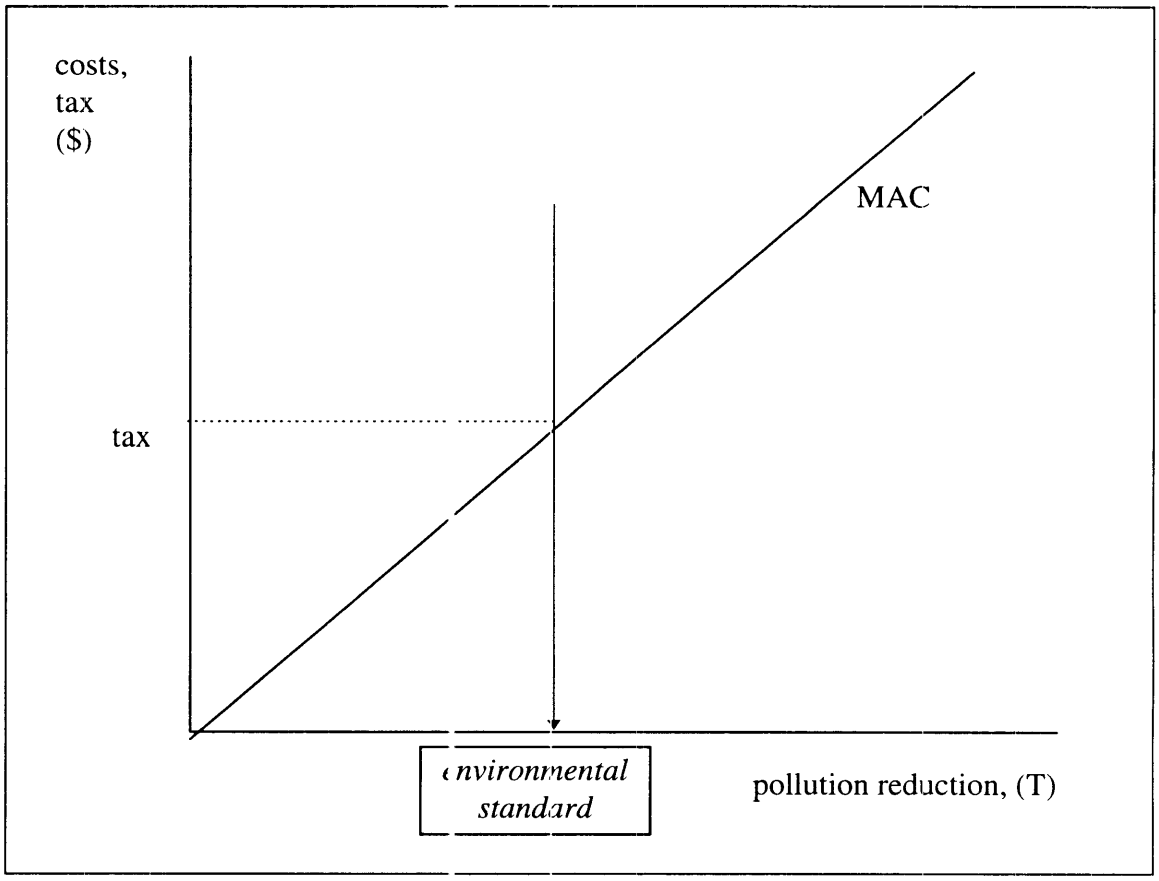


Figure 2.3 Setting a pollution tax or effluent charge

Faced with a tax on each unit of pollution discharged, the individual discharger needs to determine the level of discharge which will minimise costs. This is done by each discharger reducing pollution to the point where the marginal cost of abatement equals the marginal tax rate, based on his/her own marginal abatement cost curve. The level of abatement which will minimise the cost for an individual discharger is presented in Figure 2.4. The discharger would abate pollution up to the level of **a**, since this is cheaper than paying the tax. Pollution in excess of **a** would not be abated, but discharged to the environment (at a marginal cost equal to the tax rate). The total tax and treatment costs are given by the areas under the marginal cost curves, thus

$$\text{Total cost} = TAC + TAX_{total}. \quad (2.1)$$

where TAC equals total (variable) abatement costs, and TAX_{total} is the total tax for the level of pollution discharged. One of the advantages of the pollution tax or effluent charge over the Pigovian tax is that the firm no longer has to be profit maximising, only cost-minimising. This means that the assumption of perfect competition can be relaxed (see Pearce and Turner 1990).

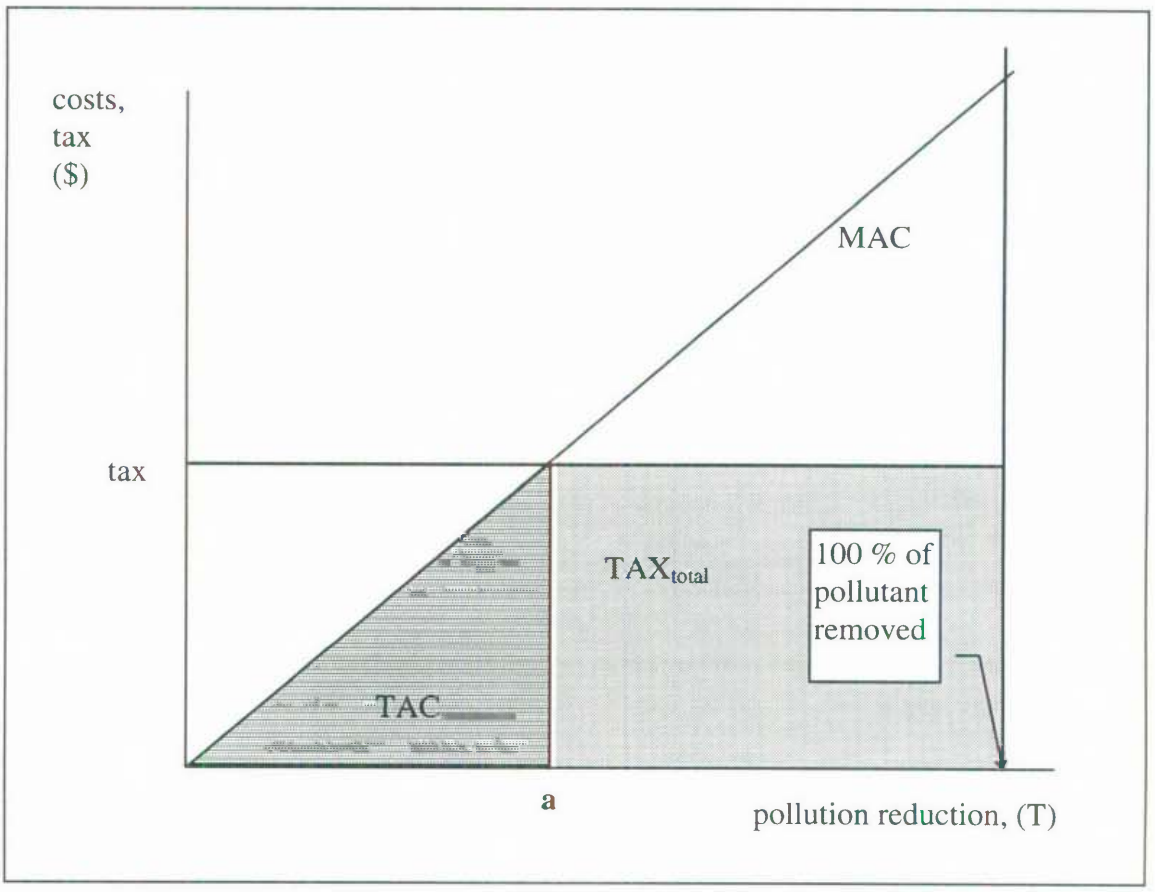
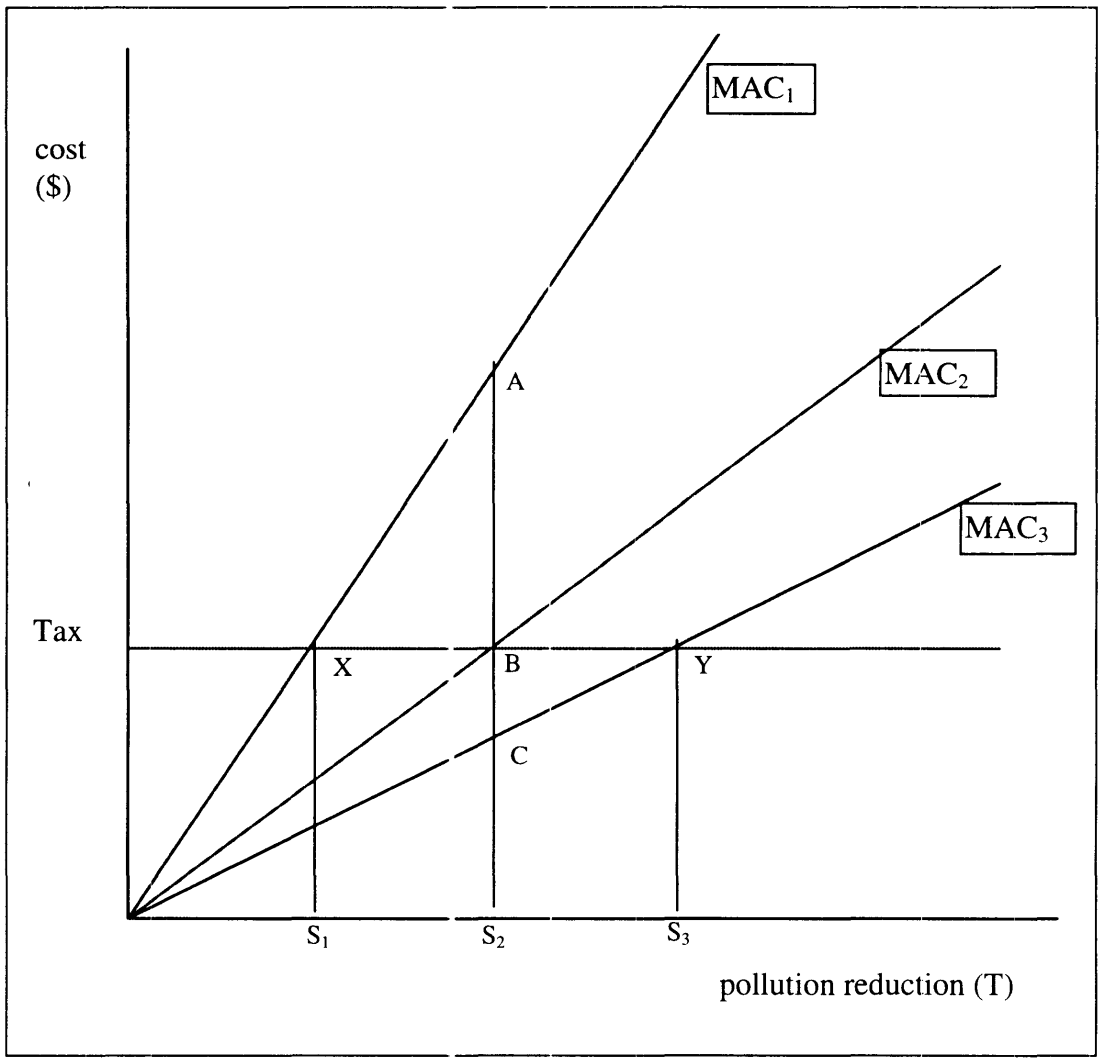


Figure 2.4 Tax and abatement costs of achieving the environmental standard

2.4.2 Achieving the environmental standard at low cost

Consider three discharging firms (Figure 2.5), all with different marginal costs of abatement (MAC_1, MAC_2, and MAC_3). The different abatement costs might occur because of differences in plant size and equipment, or differences in access to technology. The different MAC curves translate into each firm having different optimal levels of pollution discharge. Figure 2.5 shows firm 1 reducing pollution to S_1, firm 2 reducing pollution to S_2 and firm 3 reducing pollution to S_3, each level of abatement

corresponds to the point where the firm's MAC equals the tax rate. Up to this point abatement is cheaper than paying the tax. The MAC is equalised among dischargers.



Source: Pearce and Turner 1990, p95.

Figure 2.5 Taxes as a low cost method of achieving a set level of pollution reduction

For simplicity assume that $S_1S_2=S_2S_3$ and that $S_1+S_2+S_3=3S_2$. Allowing each firm to discharge at their individual optima, represents a potential cost saving to society over a more rigid quantity control structure. Under the tax system the three firms reduced pollution by the sum $S_1+S_2+S_3$. Under a direct control policy such as a quota or standard and penalty approach, with all firms reducing pollution by the same amount, the same outcome would be achieved, if each firm reduces pollution by $(S_1+S_2+S_3)/3$ (that is, S_2). The marginal cost of abatement for this level of pollution reduction is considerably higher for firm 1 than for firms 2 and 3, where the firms experience

marginal abatement costs of A, B and C respectively. The total cost of each alternative is given by the relevant areas:

For standard setting; Total abatement costs = TACst = $OAS_2+OBS_2+OCS_2$
For tax setting; Total abatement costs = TACtax = $OXS_1+OBS_2+OYS_3$
The difference is:
TACst-TACtax = $S_1XAS_2-S_2CYS_3$.
Clearly, $S_1XAS_2 > S_2CYS_3$, therefore, TACst>TACtax.

Pearce and Turner (1990) provide a graphical proof of this model and Baumol and Oates (1988) provide an algebraic proof.

While allowing dischargers to discharge different levels of pollutant presents a potential cost saving to society, how can we be sure that the environmental standard is not being compromised? To answer this question, we need to look at the aggregate level of pollution. This is best illustrated on a graph with the independent variable (on the horizontal axis) of total pollution rather than level of pollution reduction (see Figure 2.6). Observe that changing the independent variable causes the MAC curves to have a negative slope. The individual abatement cost curves for two firms are summed horizontally to give an aggregate MAC curve (please note that Figure 2.6 differs from Figure 8.2 in Pearce and Turner (1990), where a mistake has been made in the aggregate MAC curve). Figure 2.6 demonstrates that when tax=T_1, the sum of the individual levels of abatement for firms 1 and 2 gives the environmental standard. That is, S_1+S_2 = environmental standard. Thus when firm 1 and firm 2 are discharging, the horizontal summation of MAC_1+MAC_2 provides the appropriate curve to use for setting the tax.

Any factor which causes a difference between the MAC curve used to set the tax, and the sum of the individual polluter MAC curves, will cause pollution levels to be either higher or lower that the environmental standard. This is shown in Figure 2.7 where a third firm enters the discharging area, with a MAC curve of MAC_3. At the tax level (T_1)

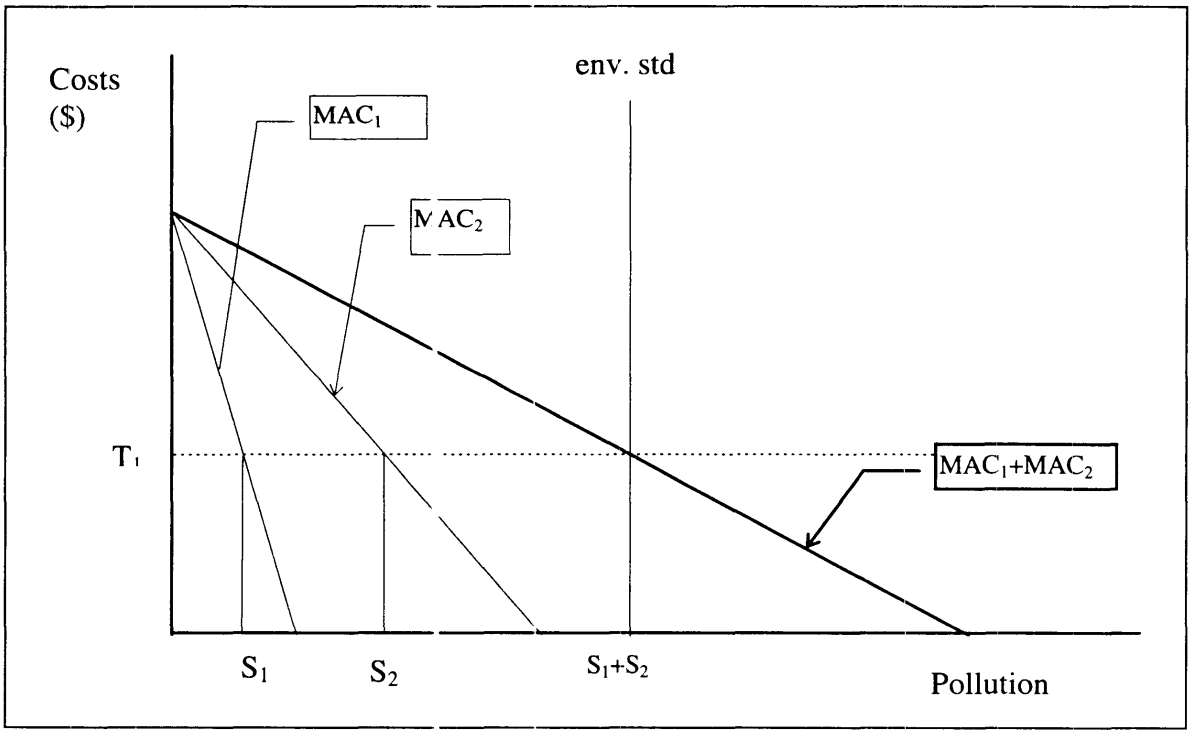


Figure 2.6 Aggregate MAC curve and meeting the environmental standard

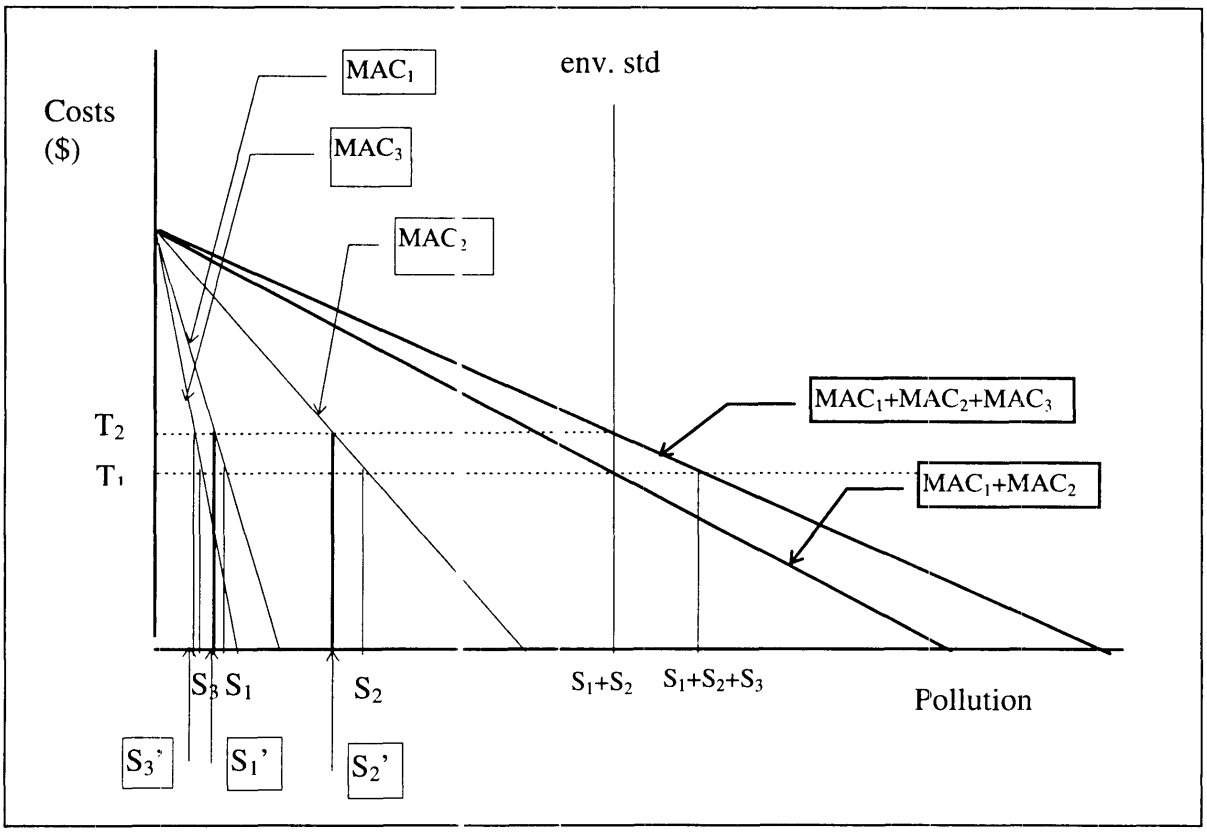


Figure 2.7 Aggregate MAC curves and tax setting

set using the aggregate curve for the two firms, Firm 1 will pollute at S_1, firm 2 at S_2 and firm 3 at S_3. This leads to a combined pollution level ($S_1+S_2+S_3$) which is greater than the environmental standard. Thus the tax rate is inappropriate. If MAC_3 is also summed horizontally to give the aggregate MAC curve $MAC_1+MAC_2+MAC_3$ then the tax rate will be increased to T_2 and the pollution levels of the three firms will be reduced from S_1 to S_1', from S_2 to S_2' and from S_3 to S_3'. The sum of these new pollution levels now equals the environmental standard.

If the aggregate MAC curve is lower than the one used to set the tax (for example if a firm leaves the discharging zone), then the tax rate will be too high and pollution levels will be less than the environmental standard. If on the other hand, the aggregate MAC curve is higher than the curve used to set the tax (for example if a firm enters the discharging zone), then the tax rate will be too low and excess pollution discharge will occur, causing the environmental standard to be violated. Figure 2.7 illustrates the divergence between the environmental standard and actual pollution levels which result when the aggregate MAC curve used to set the tax is not the sum of the individual MAC curves of the discharging firms.

Other factors which may alter the aggregate MAC curve include technological advances which may reduce the aggregate MAC curve and so create a need for the tax to be lowered. Alternatively an increase in the price of an input in the abatement process may increase the cost of abatement significantly, resulting in the need for the marginal tax rate to be increased if the environmental standard is to be met, and discharge is not to exceed this threshold.

2.4.3 Taxes and the equity question

One of the advantages often claimed of taxes is the pressure that they put on dischargers to constantly seek cheaper methods of abating pollution (for example, Baumol and Oates 1988; Pearce and Turner, 1990). On the surface it is hard to find fault with this benefit, however the pressure to find cheaper abatement stems from possibly inequitable charging in the first place. Dischargers are taxed on every unit of pollutant which is discharged, even if the level of pollutant does not violate the environmental standard. It appears that dischargers are being penalised twice. Once by reducing their discharge to

the point where the marginal cost of abatement equals the tax rate (and therefore having to abate or reduce production) and then paying a tax on the remaining pollution, which does not violate the environmental standard. Figure 2.8 shows the area of tax paid is TAX_T. This amount is paid despite the level of pollutant discharge already being reduced to achieve the environmental standard.

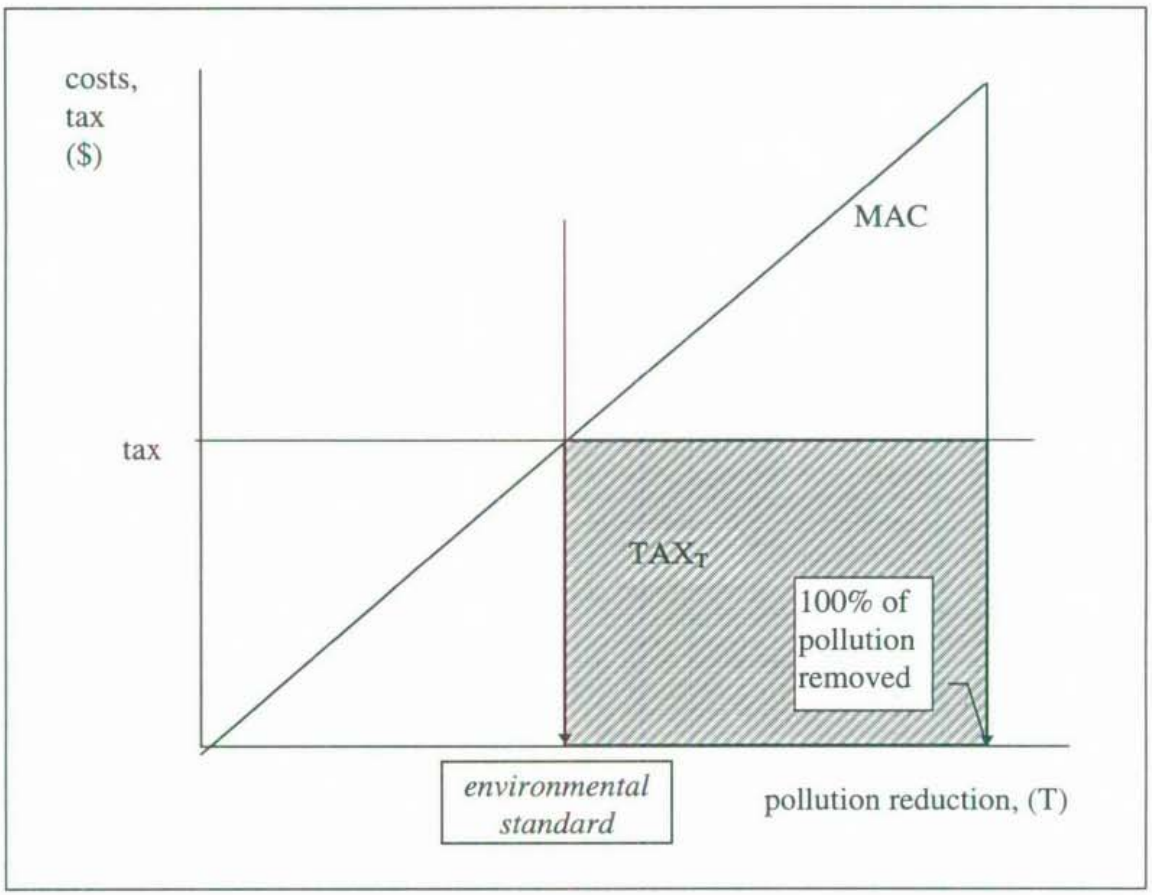


Figure 2.8 Taxes and the question of fairness

Whether or not it is equitable to make the polluter pay twice depends on one's view of property rights (Pearce and Turner 1990). If the right to use the river to assimilate waste up to the point of the environmental standard belongs to the dischargers then the concept of the tax is clearly wrong, whereas if the right to unpolluted water belongs to society, then the tax is justified. It is possible to take this point one step further.

If optimal pollution does exist, then by definition, any pollution level which is either less than or greater than this level will be suboptimal. This is because the costs of

reducing pollution below the level deemed optimal, outweigh the benefits of doing so. Hence, if a policy which encourages the continued reduction of pollution below the optimal level is implemented (as in the case of Pigovian taxes), then resources will not be allocated efficiently. This can be directly translated to a tax policy which substitutes an environmental standard for the optimal level of pollution.

Jacobs and Casler (1979) embrace this argument, and have attempted to reduce the burden on polluters by suggesting an alternative effluent tax policy. The policy suggested does not charge polluters for discharges up to the environmental standard, and enforces a tax only on discharges which exceed the standard.

The effluent tax policy suggested by Jacobs and Casler (1979) attempts to eliminate the area TAX_T seen in Figure 2.8 by allowing free discharge up to the level of the environmental standard. However the paper is flawed in its logic, which claims the benefits of taxes as a cost-minimising policy tool, while at the same time imposing quantity control mechanisms which are similar to a standard and penalty approach. In order for the tax to meet the environmental standard, the dischargers must be told what the discharge level is which will not attract the tax. In so doing, the regulators must not expect to collect any tax revenue at all, since this would mean that excess discharges occur, causing the level of pollution to exceed the environmental standard. Therefore, the free discharge threshold equates to a standard and penalty approach, where the standard is invoked on all dischargers, and the penalty is the tax. Under this scenario the tax is a penalty, and only needs to be greater than, not equal to, the MAC needed to achieve the environmental standard. Any cost advantages a tax might offer cannot be claimed when a quantity restriction is given in this manner. Effectively, all discharges above the threshold must be avoided since further discharges will violate the environmental threshold.

The tax developed in Chapter 4 aims to minimise the tax paid by dischargers without compromising the price incentive approach.

2.4.4 Revenue raising

One of the major features of a tax is its ability to raise revenue. However attractive this may seem to governments and certain sections of the community, revenue raising may prove a serious political obstacle to getting a tax policy accepted and implemented. Three possible actions which could minimise this obstacle are; using taxes to reduce income tax, using taxes to subsidise the removal of pollution from discharges and rivers, and use revenue raised from pollution taxes to address other pollution issues. There are several examples in the literature which suggest that 'green' taxes be used as a source of revenue for the government, allowing income tax to be reduced (for example, Swedish Ministry of Environment 1991; Lee and Misiolek 1986). This raises the possibility that the 'green' taxes may be set inefficiently because the objective of reducing pollution to an environmental standard is replaced with one of raising revenue. In addition, the tax should be reduced as the environmental standard is approached, and as abatement techniques become cheaper. Hence, as the environment becomes cleaner, there will be a reduced tax base. Thus while 'green' taxes may be able to supplement income taxes in the short term, they would be unable to do so in the long term.

Using taxes to subsidise removal of pollution could include subsidising 'end of pipe' treatment processes, or research into cheaper sources of abatement, methods which avoid production of the pollutant. When subsidies are used, care must be taken to avoid sending incorrect price signals to polluters. In Denmark, experience shows major problems when revenue raised from effluent charges are used to subsidise 'end of pipe' treatment. Rather than encouraging the reduction of pollution as taxes are meant to, the subsidy encourages the use of treatment plants. As the number of treatment plants increase, the demand for pollution also increases since the treatment plants rely on pollution to generate income. These distorted price signals cause great inefficiency, and misguided investment in the attempt to reduce ambient levels of pollution (Andersen, 1991).

2.4.5 Assimilative capacity and violation of the pollution target

In a discussion on the nature of socially efficient pollution taxes, Tietenberg (1980) draws attention to one of the major difficulties in pollution regulation. Namely, the problem of trying to specify the appropriate level of waste product that can be

discharged and still meet the pollution target. This difficulty arises because pollution, as it occurs in the environment, is measured in terms of concentration, whereas, the pollutants (or waste products) which cause the pollution are measured on a weight basis. Of course this is true not only for taxes but also for the majority of transferable discharge permits and, indeed, any policy which aims to achieve a given level of pollution by limiting the discharge of waste products. The implications from this observation are far reaching. For example, the relationship between pollutant and pollution concentrations may be very complex and depend on factors such as climatic conditions, geography and chemical reactions. The net effect of this is that, although a per unit tax for each type of waste product may achieve a cost-effective reduction in total *waste products* at the discharge point, this tax system may not equate to achieving the socially efficient pollutant *concentration* (environmental standard) which is the real policy objective (Tietenberg, 1973).

This dilemma holds true for even the simplest type of pollutant (for example, a single pollutant which is uniformly mixing and dilutable). Consider salt discharged into a river. The final salinity measurement in the stream will be a function of the initial streamflow and the initial salinity, since the ability of the stream to assimilate salt is dependent on its capacity to dilute the salt. Streamflow in most Australian rivers, is highly variable and unpredictable. Thus charging a per unit tax on salt discharged to the river will only satisfy the environmental standard if the river flow has a low enough initial salt load to allow the extra salt to be diluted sufficiently to meet the salinity (concentration) standard. This variability in stream assimilative capacity is extremely difficult to accommodate in a system of taxes, which are typically set for periods of one year or more, and are often based on average annual conditions of the receiving body (that is, stream or air).

In a highly variable environment with large and unpredictable changes in assimilative capacity, it is clear that the average annual conditions of the environment will lead to periodic violations of the pollution target and, equally as inefficient, it will result in under-utilisation of the assimilative capacity of the stream. This is because the

environmental standard may be violated even when the dischargers reduce pollutants to the level desired by the regulators.

When setting a tax or permit based on the weight of pollutant which regulators estimate will lead to pollution concentrations equal to the environmental threshold, knowledge of the risk of violation is important, as this will give regulators better information on which to base the tax or the number of permits. Rossman (1989) developed a method for designing seasonal discharge programs which can limit the risk of violating the standard in any year to a predetermined number. The probability that the environmental standard will be violated, based on historic streamflow and conductivity data, is calculated and a value put on the risk of violating the standard. This method allows the regulator to determine the risk of exceeding the environmental threshold once, twice or any number of occasions of interest.

The problems of assimilative capacity and meeting pollutant concentration standards are magnified when more complex interactions occur, for example biological and chemical breakdown, interaction between pollutants, adsorption and release from sediments and non-uniformly mixing pollutants. Complex modelling of the behaviour of the pollutants is needed in the specific receiving body. For non-uniformly mixing pollutants, location of discharge becomes important as the damage function will be location-dependent, and different tax rates may need to be included for different locations. This is also reflected in the broad spectrum of transferable discharge permit designs suggested in the literature which aim to address the problem of location dependence (for example, Baumol and Oates 1988 ch.12; Letson 1992)

While location of the source of the pollutant can be a major consideration, a more fundamental concern is how to integrate changing assimilative capacity into a policy. The following three approaches are derived from the literature on transferable discharge permits, however, they could quite easily apply to taxes too.

2.4.5.1 The conservative approach

One way to attempt to minimise the violation of an environmental standard is to set allowable discharges on the basis of worst case conditions, such that even rare events

will not cause the concentration level of pollution to be exceeded. For example, using critical low flow stream conditions such as the lowest seven-day average flow expected to occur once every ten years (Noss and Gladstone 1987). Other examples offered by Noss and Gladstone (1987) include the use of a critical temperature or a particularly sensitive organism which will reflect the quality of the water. The major drawback of this criterion is that, for the majority of the year, surplus water quality will result, while some risk (although small) of violating the pollution target level still exists. The cost to society would be high because of the high level of pollution abatement that is required, and the possible loss of otherwise viable industries forced to close through excessive demands for pollution abatement. From a cost-minimising perspective pollution should reach the environmental standard (but not exceed it) as often as possible, since considerable savings in capital and operating costs can result when relatively large discharges are permitted during times when the receiving body can assimilate large waste loads (Eheart, Brill(Jr), Lence, Kilgore and Uber 1987). Seasonal waste emissions and variable waste emissions are two ways of attempting to meet the environmental standard more closely, and hence to capitalise on these cost savings.

2.4.5.2 Seasonal waste emissions

Where the receiving body, experiences periodic changes in assimilative capacity, the level of waste can be varied according to some predetermined calendar date such that the pollution target is met more often than if the average annual assimilative capacity were used. This type of variation in the level of wastes discharged has been suggested in much of the literature relating to transferable discharge permits (Noss and Gladstone, 1987; Eheart 1988; Rosensteel and Strom 1991). As noted in Dudley, Coelli and Pigram (1993), the terminology used to describe seasonal variations in allowed discharges, is confusing. Where the majority of permits vary according to a predetermined calendar date, they are termed variable flow permits or periodic permits, while those that vary on the basis of actual stream conditions are referred to as conditional permits.

While the literature is quite detailed on seasonal or periodic discharge permits, the same is not the case for taxes. Theoretically, taxes could be varied to achieve the same waste discharge on a periodic basis, with similar attainment of the pollution standard as for the

permit system. Compared to permits, however, taxes have the added uncertainty of needing perfect knowledge of the MAC curve.

2.4.5.3 Variable waste emissions

Variable waste emissions do not vary according to a predetermined calendar date but are indexed to changes in the actual assimilative capacity of the receiving body. Typically, they involve a much finer time grid, and allow for greater control of pollution discharge. A good way of picturing the array of options is to consider the conservative (static) approach at one end of a continuum of options and a variable or conditional permit which is altered at least daily at the other end. The basis for determining the acceptable waste load could vary widely. It could use trigger values on the basis of critical streamflow (Noss and Gladstone, 1987), or use daily weekly or monthly average values. Alternatively critical low flows could be used, as for the conservative approach, but altered on a more regular basis.

Determining acceptable waste loads on the day of discharge, would place significant costs, on both the public and private sectors. The possibility that the costs of varying allowable discharges daily could be prohibitive is suggested by Tietenberg (1980), public costs would be high because of the necessity to continually update and transmit the information to the firms, and private costs would be high because it would be difficult to plan production schedules. These comments were made with reference to air pollution permits, but they are equally as relevant for water pollution permits. From the perspective of tax setting, the costs may even exceed those associated with permits due to the informational burden, transferred to the discharger, of deciding on the cost minimising level of discharge. These reservations should be borne in mind as practical limitations to implementation of the tax formulated in Chapter 4. Chapter 7 will discuss these more fully.

2.4.6 Transferable discharge permits

Transferable discharge permits are a quantity control mechanism, whereby pollution permits are issued for the allowable level of pollution only. The permit system is essentially the same as a direct quota control system, except that the permits are transferable. By offering permits for sale to the highest bidder, the market clearing price will indicate to polluters the opportunity cost of pollution. In so doing the marginal

costs of abatement are equalised across polluters (Misiolek and Elder 1989), and the cost-effective outcome is achieved.

Transferable discharge permits address market failure caused by externalities by establishing clearly defined property rights. Whereas, Pigovian taxes directly charge the discharger for the external damage costs associated with pollution, transferable discharge permits attempt to address the property rights issue. Dales (1968) is widely credited with introducing the idea of transferable discharge permits for water pollution. By recognising that market failure often occurs because property rights are not adequately defined, enforceable, or transferable, Dales (1968) showed that the right to use water as a waste disposal service could be removed from the physical ownership of the water itself, and offered for sale to the highest bidder in a market setting.

Transferable discharge permits have the same cost-effectiveness qualities as taxes because the regulator allows the discharger to determine their own optimal level of permits and hence discharge. Trading in permits allows dischargers to concentrate their control efforts on those pollutants which are cheapest to control. The informational requirement for regulators is less than for taxes, because the regulator needs only know the environmental standard, and is not required to know the marginal cost of abatement. The resources required to efficiently set pollution taxes are high and the ability to accommodate new pollutant sources and changes in the marginal abatement cost curve is limited. Transferable discharge permits, on the other hand, easily accommodate such changes by transfer of permits and fluctuations in the price of permits.

The initial allocation of discharge permits is generally achieved by either grandfathering or auctioning. Both these methods are outlined briefly below.

2.4.6.1 Allocation of permits by grandfathering

When permits are grandfathered, they are given out to existing firms at no cost (BIE, 1992). The permits tend to be distributed according to some pre-determined rule, such as the current levels of emission, or the current standards. Examples of these and other rules are given by Hahn and Noll (1982) and Eheart, Joeres, and David (1980). In general, the success of a transferable permit system is measured in terms of the number

of trades that occur. Thus, even when the environmental standard is achieved, if trades do not occur because the initial distribution of permits is close to the equilibrium distribution, a transferable permit system is not considered to be able to achieve the cost efficient outcome. Few trades mean that the market mechanism is not able to establish a competitive permit price (Hahn and Noll 1982). Without knowledge of the competitive price of permits important information on the costs of abatement and changes in the demand for permits is unavailable. These price signals would be regularly updated in an operational market, and they would be essential to firms in order to make cost-effective investment decisions (for example in pollution abatement plant and equipment).

2.4.6.2 Allocation of permits by auction

The other major alternative to grandfathering is to allocate permits by auction. Two major features are that the controlling authority earns revenue, and that new source bias is eliminated since all sources must purchase their permits (BIE, 1992). A variant on traditional auctions is offered by Eheart et al (1980), where all dischargers submit demand schedules and these are then aggregated into a combined demand curve, from which the appropriate price and quantity of permits can be allocated to all participants. Inventive methods have been suggested to achieve revenue neutral (or transfer-neutral) auctions, where the controlling agency does not earn any revenue. This may be a decided advantage to achieving implementation of a transferable permit system, where a polluting industry has large lobbying power. Examples of revenue neutral auctions include incentive compatible auctions, where bidders receive equal lump sum refunds; non-incentive compatible procedures, where refunds are a function of participants' bids; and free initial distribution of permits on a lump sum basis, followed by trading in a competitive market (Hahn and Noll 1982; Lyon 1986).

2.4.6.3 Making assimilative capacity work for transferable discharge permits

One of the major differences between taxes and discharge permits is that discharge permits are a quantity control which can more closely regulate the quantity of pollution in the system. It is important to note that transferable discharge permits experience a similar level of inefficiency to taxes when the permit allows discharge of a set weight of discharge, and does not allow for changes in assimilative capacity. Assimilative

capacity can be integrated into the permit in the same way as discussed for taxes in section 2.4.5., however the quantity control nature of the permit system will provide a tighter control on the level of pollutant entering the environment. Thus the risk of violating the pollution standard is reduced with the use of permits over taxes, but both systems will ultimately be limited by the ability of the regulator to accurately assess and/or predict the assimilative capacity of the environment and make the appropriate connection between the weight of pollutant emissions and the resulting concentration of pollutant in the environment. Discharge permits can address this problem by entitling dischargers to a percentage share in the assimilative capacity of the receiving body. This will force the dischargers to carry the risk of violating the threshold, however it will significantly increase their operating costs since the level of pollutant discharged will vary enormously. It may also make enforcement costs considerably higher than for alternative permit systems allowing set weights of pollutants to be discharged. Obviously this type of permit would be useable by those firms who are able to respond quickly to changes in assimilative capacity, but firms with more complex treatment processes may be severely disadvantaged by such permits.

2.4.6.4 Longevity of Permits

Transferable discharge permits entitle the bearer to discharge certain levels of waste to the receiving body for a certain period of time. The rights associated with the permit need to be enforceable and long term if investment in efficient, technologically advanced abatement equipment is to occur. Short term permits may also present a barrier to trade as the permits would be unattractive to potential purchasers if they expire shortly after purchase, with no rights for re-issue. It seems intuitive that the true opportunity cost of pollution will not be reflected in the price of permits unless the rights are extremely long term.

2.5 The choice between policy instruments

The choice between policy instruments will depend on the type of pollutant. A pollutant which is highly toxic and non-degradable, will lend itself to direct controls where a strict standard can be enforced. This is of most benefit where the damage costs are extremely high from relatively small amounts of pollution. Pricing policies which include taxes have a role where the system is fairly static, where entry of firms is slow,

where information on the abatement cost curve is available and in instances where it is believed that the polluter should pay to use the environment for the assimilation of waste, even though that waste does not exceed the environmental standard. Policies of quantity control using the market system, namely transferable pollution permits, are superior where the right to pollute can be captured comprehensively in private property rights. The single biggest advantage is that the regulator only needs to know the environmental standard, and needs no knowledge of the marginal benefit curve or the marginal abatement cost curve, since the market mechanism allocates the property rights to those who have the highest costs of abatement. Providing that there are sufficient polluters for a market to operate and strategic behaviour is limited, transferable permits are preferable in dynamic situations, where entry and exit of firms is frequent, and where technology permits a rapid change in the marginal cost of abatement.

Support for economic instruments over direct control to achieve an environmental standard at minimum cost is voluminous in the literature, and the magnitude of suggested savings varies widely. Baumol and Oates (1988) provide formal proofs that pollution taxes and transferable permits have cost-minimising qualities which satisfy the cost-effectiveness criterion described by Tietenberg (1980). The cost-effectiveness criterion is considered to apply to pollution charges which have been designed to achieve a predefined ambient standard at the lowest possible control cost. It is distinct from pollution charges designed to produce an efficient outcome by forcing the polluter to compensate completely for all damage caused.

In contrast to the cost-effective policies, the direct control approach which has been the traditional response of governments, does not satisfy the cost-effective criterion (Tietenberg 1980; Baumol and Oates 1988 and Pearce and Turner 1990). The magnitude of the cost savings experienced by cost-effective policies cannot be directly observed, as there are no examples of policies meeting this narrow criteria in operation. Empirical studies support the theory that cost savings from the use of economic incentives rather than direct control can be significant. Tietenberg (1990) has compiled evidence from ten air pollution studies which empirically show the savings in cost from

cost-effective policy tools were between 2 and 22 times greater than the command and control policies used to achieve the same environmental standard.

2.5.1 Scope for combining policy tools

The combination of a tax together with a direct control may present the opportunity to take advantage of the cost-minimising advantages of a tax, while at the same time ensuring a safety net to protect the environment from the low risk extreme pollution events. Discussion of some suggested policies which combine policy tools for use in stochastic environments is given in Baumol and Oates (1988).

2.6 Evidence of the use of transferable discharge permits for the purpose of controlling pollution in water ways

Although the most successful and dominant use of transferable discharge permits has been for the control of air pollution in the US, transferable discharge permits have been implemented to solve water pollution problems. These include the Fox and Wisconsin River BOD (Biochemical Oxygen Demand) permit programs and the Lake Dillon (Colorado) point/non-point source phosphorus trading program. For the Fox and Wisconsin Rivers, the main water quality problem was high BOD loads from papermills and towns. On the Fox River, 21 dischargers in 35 miles are involved while there are 26 dischargers over 500 miles on the Wisconsin River. The allowed discharge varies daily and is dependent on river flow and temperature (Howe 1994). Permits are valid for five years only (BIE 1992). Only one trade has occurred on the Fox River since it was implemented in 1981, and none on the Wisconsin. Hahn and Hester (1989) suggest the reason for lack of activity in the market is over-regulation. The regulation of the permits and their trade ensures that the market remains thin, and as such, trade will be unattractive. Howe (1994) suggests that, in addition to thin markets, there are neither independent "arms-length" relationships among the firms, nor a significant difference between the abatement costs of the firms, hence trading is inhibited.

Lake Dillon, Colorado, has a significant eutrophication problem due to excessive levels of phosphorus. Point sources and non-point sources both contribute to the problem, although studies in the early 1980's showed that non-point source control was more

cost-effective than additional point source treatment. The point/non-point source trading program gave an initial allocation of permits to treatment plants. Plants could offset excess discharges by financing non-point source control projects, based on a 2:1 trading ratio to allow for uncertainties in the control of non-point pollution (Howe 1994). The idea was meant to limit phosphorus discharges while at the same time permitting development in local government areas. As for the Fox River project, trade has not lived up to the expectations of the controlling authorities. Early in 1992, only one point/non-point source trade had been effected, while two non-point projects were initiated to offset other non-point sources (Howe 1994).

2.7 Evidence of the use of taxes for the purpose of controlling pollution in water ways

In general, Europeans have had experience with various systems of fees and charges on discharges to water ways, but have not used transferable discharge permits while the reverse is true in the US (Howe 1994). The European experience of fees and charges does not include many, if any at all, that can claim taxes to have been set with the primary objective of achieving an environmental standard at low cost. One case which approaches a cost-effective tax is in the Netherlands, where taxes have been charged on all polluters, including households, at a high rate. Although some of the revenue raised has been used to subsidise treatment of pollution, it has also been used to fund research into cheaper abatement technology In general, however, taxes have been inefficient in Europe, where they have been set too low to achieve reductions in discharges and the revenue has been used to fund 'end of pipe' treatment which is known not to be the cheapest method of abating pollution (Howe 1994; Andersen 1991).

The use of taxes to control pollution in water ways in Germany is reviewed by Brown and Johnson (1984), with a view to possible implementation of similar taxes in the US. The effluent charge system is judged to be most successful if it covers a small number of pollutants which are easily measured, it is combined with permit systems, and charges begin at a specified level and escalate during a transition period. The level of tax should be set in a collaborative environment between dischargers and parties harmed by the waste discharge. If a similar system is introduced in the US., Brown and Johnson

(1984) claim that one of the major benefits will be that dependence on the Treasury will be decreased and that this will lead to a redistribution of costs of pollution from the taxpayer to the consumers of the pollution producing products.

2.8 Summary

This chapter provides a review of the theory and application of cost-effective policy tools. In essence, if a discharger is able to decide on the level of discharge which minimises their individual costs, then a cost-effective outcome is likely. Both taxes and transferable discharge permits are shown to have this characteristic. In the case of taxes, the discharger is notified of the tax rate only, and is able to discharge the level of pollutant which minimises costs (that is, where MAC=tax rate). Transferable discharge permits achieve the same outcome (at least in theory), by enabling the discharger to purchase the quantity of permits which allows the discharger to release the quantity of pollutant which minimises costs (that is, MAC=permits). For taxes to be cost-effective it is essential that the regulator set the tax rate and in no way attempt to regulate the quantity of discharge allowed by individual dischargers. Under a permit scheme dischargers must be permitted to purchase any quantity of permits without additional quantity restrictions.

In addition to reviewing the cost-effectiveness of taxes and transferable discharge permits, the chapter highlights some of the equity issues associated with the polluter pays principle and taxes, and demonstrates some of the pitfalls that are associated with attempts to redress these inequities. The following chapter discusses the pollution problem in the Hunter River System with a view to developing the simulation model in Chapter 4.