For the Student

Environmental Economics

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1. Introduction

Applying economic analysis to natural resource and environmental issues has been a booming activity in recent decades. Increased awareness of environmental damage, our dependency on natural resources, and the costs of economic growth has been reflected in the economics profession as everywhere else. This awareness has led to major growth in environmental economics as a discipline, as reflected in a large number of academic articles on the subject, as well as the appearance of a number of specialist journals to handle these papers; the important contributions to the subject made by a number of very eminent academic economists; the growing number of specialist undergraduate textbooks in the field; and the increasing role applied economists are having in the *policy* advice process concerning resource and environmental issues (although they would perhaps wish for more influence than they have).

To some, the boom in environmental economics is, at best, a mixed blessing. The upside is that at last economists appear to be becoming aware that all economic activity occurs in a wider framework, in which the natural world has been an important but neglected component, both as a source of materials and a sink for wastes.

The downside is that, for some, looking at the environment through the lens of economics is either an oxymoron or a betrayal, or both. Economics is seen as being concerned with materialism and consumerism, with wealth and greed. The environment is perceived as representing higher values than mere dollars. Altruism, even spiritualism, are associated with environmentalism in a way that is seemingly incompatible with the bottom-line focus of economics; and that to take an economic view of the environment is to reduce it to its lowest possible denominator.

While it is quite possible to have a sophisticated version of this argument,[1] at its simplest, the position spelled out above simply misunderstands or ignores the most important issues. The fact is that all societies, regardless of technological structure or economic system, have an impact on the natural world around them. The real problem facing any society is that of making choices about the impact it has, in light of its various other goals, all of which contribute in some way to the quality of life.

In other words, given humankind is going to change the world in physical ways, the question is which impacts are acceptable, and to what extent, and how should unacceptable impacts be dealt with? Trade-offs between desirable things (wetlands, forests, hospitals, episodes of *Seinfeld*) have to be faced; and given these trade-offs, different choice mechanisms[2] will suggest different final choices. Economics has a valuable role to play in understanding these questions.

In this article, the foundations of economics as it can be applied to environmental issues are spelled out (Section 2). The market's role as an allocative mechanism is described, and the notion of market failure is discussed (Section 3). The basic economic analysis of pollution control and environmental valuation is presented (Section 4). Key domestic and international examples are then reviewed as examples of how the theory might be applied (Section 5). Section 6 concludes the article.

2. Descriptive and Prescriptive Analysis

2.1 *Two Types of Analysis*

In economics textbooks, it is conventional to make a distinction between two classes of economic analysis. Although the distinction is a standard one, it is neither uncontroversial nor unambiguous.

The first type of analysis, **positive economics**, is in a sense a form of 'behavioural science'—seeking to be descriptive or predictive regarding the consequences of some action. In particular, it seeks to provide 'if-x-then-y' statements linking causes with effects.

The first underpinning of positive economics, *methodological individualism*, concerns the unit of analysis: that is, we start at the level of individual choice and action, and build up to a bigger social picture. (It does *not* imply that any analyses with such individualist foundations are necessarily divorced from a broader social context.)

The second underpinning is an assumption about individual human action. In particular, *'rational' self-interest* is assumed. This assumption does not automatically imply (or promote!) selfishness in behaviour; it does imply that people pursue what they think is in their interests to pursue. Their interests may be linked in their own minds with the interests of others (including other species).

The second type of analysis, **normative economics**, provides a framework for making judgements about what is 'better' or 'worse': that is, it is explicitly prescriptive regarding the possible consequences of different actions, giving us a means by which choices can be assessed. (The choice might be whether or not to build a dam; to ban or allow logging in a sensitive area; to change the way water is allocated in rural areas, and so on.)

The underpinnings of normative economics—sometimes called *welfare economics*—are also twofold. The first is *consequentialism*: interest is centred on the evaluation of the consequences or outcomes (such as how much clean water is provided to a city) rather than the means used to achieve the clean water (by legal action against polluters, or a subsidy for treatment works). That is, the means (or processes) are assessed explicitly in terms of the ends (outcomes) achieved, rather than judging the acceptability of the means in themselves.[3]

The second underpinning follows from the postulate of rational self-interest. Here, individuals are regarded as being the best judge of their own preferences, and their own welfare. In other words, the analyst does not presume to tell people what is good for them. Instead, a decision or action is evaluated by how it affects the individuals concerned, using (in principle) their own perception of its costs or benefits to them, and a conclusion is drawn about the overall cost or benefit of some action by aggregating all the costs and benefits incurred by individuals.

It is important to appreciate the significance of this assumption. Some participants in environmental debates contend that the problem lies in us choosing the 'wrong' goals (for example, the superficial or transient benefits of consumer goods over the deeper satisfaction coming from a more frugal, natural lifestyle). While this issue can be legitimately debated, the starting point here is that we are not better equipped to judge what will make people happy than those people are themselves.

2.2 *Costs and Benefits versus Rights and Wrongs*

> [P]opular treatments [of global warming] commonly ... assume that if society learns that any warming is likely as a result of human activity, we should do whatever is necessary to stop it. This seems to reflect the widespread view that environmental issues involve rights and wrongs, not costs and benefits ...
> [Schmalensee 1993, p. 3]

Basing an assessment of environmental problems, and their possible solutions, on the costs and benefits involved, rather than on the perceived rights and wrongs of the situation, is deeply ingrained in the economist's way of thinking: sometimes so much so that, as the quote above shows, it takes them by surprise that anyone would think about the issue in any other way. The rest of this article will also focus on analysing costs and benefits—on the basis that even those who have strong views about what is 'right' and 'wrong' should be mindful of the pluses and minuses of different situations. It is one thing to advocate doing the 'right' thing; it is another thing to advocate doing the 'right' thing *regardless* of the cost of doing so.[4]

Thinking in terms of costs and benefits helps us with both positive and normative analyses of environmental problems. In terms of understanding behaviour, and how to influence it, it is important to understand how individuals perceive the costs and benefits to themselves of their own actions. As an example, imagine a tax was directly levied on the exhaust emissions from our car. If such a thing were feasible, it seems fairly clear that our driving decisions would be influenced; and the higher the tax, the greater the influence.[5]

Moving from positive to normative analysis, measured costs and benefits can be used explicitly to help guide resource use decisions. For example, decisions may need to be made regarding harvesting trees, arresting land degradation, exploring for oil, damming a river, and so on. Doing more of these things may enhance our standard of living (or quality of life) in certain ways, but may reduce it in others. We would like to weigh up the pluses and minuses to help draw conclusions about the choices facing us.

An alternative approach is to judge our attitudes, our actions, and our laws in terms of whether they seem right or wrong. In such a view, behaviour which damages the environment is 'wrong' behaviour and should be discussed as such. To use a domestic pet metaphor, cats are sometimes regarded as 'clean' or 'tidy' animals with regard to grooming and hygiene, where dogs are 'messy'. The observation is then made that humans are 'messy', like dogs, and need to become more 'tidy', like cats, if environmental damage is to be arrested. The 'messy/tidy' dichotomy has shades of a 'right/wrong' perspective: for humans (as opposed to dogs), environmental tidiness is virtuous, while messiness equates with moral slackness. This is sometimes linked to a broader social critique, usually of 'Western capitalism', which is then contrasted with other forms of social organisation which are less 'selfish' and (presumably) tidier.

This view seems appealing, but it is in fact superficial and misleading. All societies pollute. The key questions are how much, why, and how best to deal with it. Moreover, to characterise humans as 'messy' ignores the fact that people can be tidy, fastidious even, about their immediate environment; the key issue comes when examining how humans treat their broader habitat, where other people (and other species) become affected. Moral injunctions to live less wastefully, while maybe of virtue in themselves, are not likely to be adequate to address environmental problems on a global scale.

So we return to the consequentialist approach favoured by economists. Instead of characterising private actions, or public policies, as right or wrong, they are characterised as having costs and benefits which can be compared, and choices made on the basis of those.

3. Invisible Hands and Other People's Problems

3.1 Individual Behaviour and Social Outcomes

The foundations outlined above lead to a key normative result, which is originally attributable to Adam Smith. His argument was that a butcher selling meat is performing a social service, but from purely *private* motives. That is, when people pursue self-interest, the result can be mutually harmonious rather than mutually destructive. Self-interest drives people to do things that other people find valuable and are willing to pay for.

Thus a 'socially good' outcome did not depend on an authoritarian coordinator. Instead, it was as if an 'invisible hand' led self-interested people to pursue socially beneficial ends. Prices are the means by which the invisible hand functions: prices will rise or fall in response to changes in the relationship between the scarcity in supply and the extent of demand for any good.

The strong version of the 'invisible hand theorem' deserves attention: it says that a policy maker cannot change an economic outcome so as to make everybody as well as or better off than they were under the decentralised market outcome. This is a striking result: it says that competitive free markets lead to an **efficient** (that is, 'invisible hand') outcome in which an intervention that makes someone better off means someone else necessarily has to lose.

Smith's idea of the invisible hand is both profound and flawed. It is profound because it showed how decentralised and self-interested actions did not necessarily lead to social degeneration and chaos; virtually the opposite! But it is flawed, in that many things can and do cause the invisible hand to have problems; these problems are often labelled **market failures**. Market failures are situations where, *in principle*, selective tinkering with the market mechanism could lead to net gains (that is, a gain to someone can be achieved without an offsetting loss to someone else—there is a possible free lunch). This is where the economics textbooks become interesting, and where we will be concentrating our attention.[6]

3.2 Other People's Problems Interfere with Invisible Hands

The starting point of much of environmental economics has to do with a particular form of market failure, commonly referred to as an **externality**: an impact which is felt 'externally' relative to those responsible for it.

The invisible hand argument states that for every transaction, both buyer and seller gain, otherwise the transaction would not go ahead; and thus, social welfare has increased.[7] But what if a transaction causes a problem to *somebody else*, a person who is not a party to the trade? The obvious example is pollution in all its forms. Every time we drive a car, we are (generally) conforming to what we might think of as The Law Of 'Somebody Else's Problem': we pay close attention to the costs and benefits of driving as faced by us (time saved, petrol costs, parking hassles), but typically much less, if any, attention to the congestion and pollution we inflict on others. So the 'somebody elses' find their welfare is reduced even while the parties choosing to undertake the activity (the production or trade) find theirs increasing. There is a problem with the invisible hand.

The logic generalises easily. An industrial firm will simply release waste products into the air, land or water around it, unless it perceives costs to itself from doing so. The firm and its customers benefit from the goods thus produced; those affected by its waste disposal suffer later.

From a 'right or wrong' perspective, it might be argued that it is wrong to be causing a problem to a third party or parties, and such activity should be prevented, or at least severely discouraged. From a 'costs and benefits' perspective, we would want to assess how the benefits to the buyer(s) and seller(s) compare to the costs incurred by others. Typically, such an examination of costs and benefits leads to the conclusion that the activity causing the externality should be reduced, but not completely curtailed. The benefits from *some* level of goods and services typically offset the costs from *some* degree of associated pollution. But the invisible hand will perform inadequately here in trading off the various benefits and costs to all affected parties.[8]

Let us recap. Choices need to be made about various uses of our environment, between options such as utilising various parts of it as raw materials, as waste sinks, or leaving it as pristine as possible. The market mechanism is regarded as a means by which resources (natural and otherwise) can be allocated to their highest valued uses (the invisible hand argument). However, markets can fail to efficiently allocate resources when externalities are prevalent, because some costs are not borne by the party imposing them, and are not fully reflected in prices. This is often the case with environmental resources: because the true cost of environmental damage is often ignored, the costs of the damage outweigh the benefits arising from it, and some damage reduction is warranted to restore the balance. In such circumstances, we would like to find ways to 'internalise' environmental costs, so as to make the polluter mindful of the damage being caused (preferably by influencing the price mechanism, for reasons we will now investigate).

4. Principles of Environmental Economics

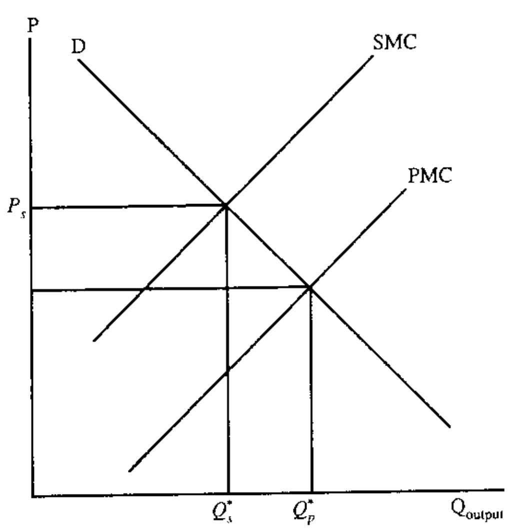
4.1 Pollution Control

In the previous section, it was argued that as long as externalities are pervasive, environmental damage will be at a level where the costs of such damage are no longer being offset by the benefits of more goods and services. That is, there is a point beyond which further production of goods and services yields greater overall costs than it does benefits, but as the environmental component of the costs falls on parties who cannot 'make the polluter pay', the costs are not factored into the production decision.

In principle, the point at which the *extra* benefits of economic activity are just offset by the *extra* costs from associated environmental damage can be found using economic analysis. To see this, use a diagram as follows. Figure 1 portrays the supply, demand, and **external cost** associated with an unspecified competitive industry.

In this diagram, the demand curve (D) reflects the willingness of consumers to purchase a greater amount at a lower price. On the supply side, PMC refers to the **private marginal cost** to the industry of its production. That is, the full cost to the firms in the industry, *excluding the cost to the environment*, of each extra unit of output is equivalent to the vertical distance between the horizontal axis and the PMC line. A higher price will call forth more output in any period.

Figure 1



Note: P_s and Q_s represent the price/quantity pair which maximises social welfare.

However, production of this good has an associated external cost, which by assumption is not borne directly by firm or consumer. If we add this external cost to the production cost as embodied in the PMC curve, we get a total or **social marginal cost** curve, SMC. Thus the social marginal cost (SMC) is the sum of the private marginal cost (PMC) and the marginal external cost.

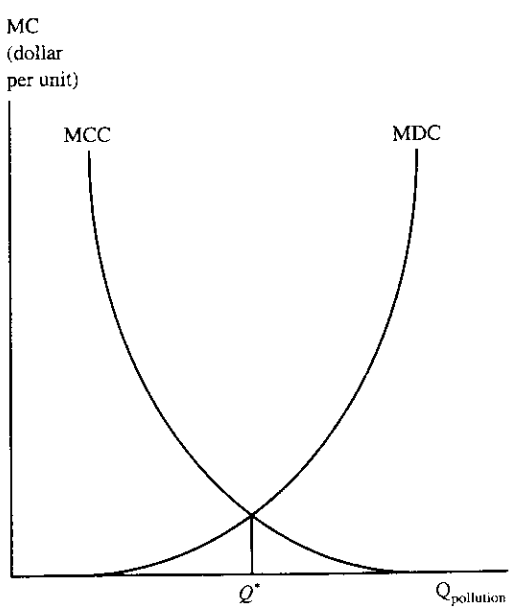
According to standard analysis, the level of output Q_p^* given by the intersection of the demand and PMC curves is the *privately* optimal outcome, that which maximises the benefits to both buyers and sellers. The reason is that the marginal benefit (from another unit of production) is equal to the vertical distance to the demand curve, while the private marginal cost is the distance to the PMC curve. At any lower level of output, firms would be willing to produce more (up to Q_p^*) and buyers would be willing to pay for it. At higher levels of output, firms would want to cut back on production as buyers are unwilling to pay enough to cover the production cost. Where the curves intersect, the market is in equilibrium and the benefits *to buyers and sellers* are maximised.

The external cost is where the problems lie. At output of Q_p^*, costs to *society* (firms *plus* pollution victims) outweigh the benefits to consumers. It is at the lower output level, Q_s^*, where marginal benefits and costs to society are equalised, and thus total net benefits maximised. In this framework, where the implicit assumption is a fixed relationship between output of the good and damage to the environment (as measured by the given distance between the social marginal cost curve and the private cost curve), the policy maker charged with reducing pollution to the ideal level would simply decree that producers set output to Q_s^*, and the problem would be solved.

Of course, the real problems which face a public authority attempting to reduce pollution in such a way as to increase social welfare are many, but here the focus will be on two classes of problem. The first involves the difficulty of determining the true costs and benefits associated with pollution emission or abatement, and therefore the 'optimal' level of pollution. The second type of problem is that of *achieving* it optimally!

Another diagram useful for representing the first problem, finding the **efficient level of pollution reduction**, is shown in Figure 2. While the vertical axis is measured in dollars per unit, as in Figure 1, the units measured on the horizontal axis are now units of pollution emissions (rather than units of outputs of the good, as in Figure 1). The upward sloping curve embodies information on marginal costs of pollution *damage*, the assumption being that each extra unit of pollution released does more damage than the previous one, as the environment's capacity to assimilate the waste is further stretched. The downward sloping curve embodies information on marginal costs of pollution *control*, the reasoning being that points further to the left involve more pollution reduction than points further to the right, and the marginal control cost rises with more abatement. (Note that these curves reflect *social* costs—the sum of costs incurred by all the affected parties.)

Figure 2



Notes: MCC = marginal control cost.
MDC = marginal damage cost.

Q^* denotes the level of pollution consistent with the intersection of the two curves. At higher levels of abatement (points left of Q^*), the cost of controlling (abating) an extra unit of pollution is greater than the cost of allowing it to be emitted, so it makes sense to allow it to be emitted (and thus move rightward toward Q^*). To the right of Q^*, the cost of the damage from another unit exceeds the cost of control, and thus it should be abated (moving leftward toward Q^*). Only at Q^* is the cost of reducing pollution equated with the cost of enduring it at the margin.

In reality, the problem of identifying the amount Q^* can seem overwhelming. How does a public authority, such as an Environmental Protection Agency, estimate accurately the environmental costs associated with each and every industry's activities, so as to prescribe the optimal level of output—or, more particularly, pollution reduction—in each one? It is a task which is breathtaking in both magnitude and complexity. The next section contains a discussion of some techniques for assigning (dollar) values to environmental amenities, which can be used to provide information on the costs of damaging those amenities. However, such estimates are difficult and costly to generate, and subject to a variety of limitations, as shall be shown.

The second problem is as follows. *Even* if the optimal level of pollution abatement, Q^*, for a particular region or industry could be determined, the question remains: How should the total required reduction in pollution be distributed across the various contributors so as to minimise the aggregate costs of the abatement? That is, what is the **cost-effective allocation of pollution reduction**?

To see why this matters, consider a simple example. Two plants, each belonging to separate firms, produce goods called widgets. They also emit an identical effluent into a river, fouling the water for downstream users. Each has a

control cost function which expresses the relationship between each unit of effluent reduced, and the cost to the firm of doing so. The marginal cost of control for each plant is increasing (as in Figure 2), but assume here that the second plant utilises more recent technology and thus is 'cleaner' in its production of widgets. For this plant to reduce emissions further is difficult, hence its marginal control cost is always higher than that of plant 1.

Imagine now that the pollution authority decrees that combined emissions from the two plants must be reduced by 100 units in total. If both plants were compelled to abate an equal amount (50 units each), the cost to plant 2 of abating the last unit will be greater than the equivalent cost to plant 1. If plant 2 abated one less unit, and plant 1 abated one more (so total emissions reduced still equalled 100), the total cost to society of the abatement would fall. In fact, as long as the marginal control cost at one plant is greater than at the other (for a given level of emissions), then total abatement cost can be reduced by reallocating the burden of abatement in favour of the plant with the lower cost. The condition for cost-effective pollution reduction is thus where the marginal control costs are equal across emission sources.

The 100 units chosen here was an arbitrary number, and may have little connection to the efficient level of pollution reduction Q^* identified in Figure 2. But, even if it is too difficult to reliably identify Q^*, the earlier discussion of externalities led to a conclusion consistent with many people's intuition: that there is somehow 'too much' pollution, and it should be reduced.

So, even if the policy choice of how much reduction should occur is made on grounds other than a trade-off of benefits and costs as in Figure 2, many economists would advocate the following principle. For any given desired level of pollution abatement (however it is chosen), the abatement should occur *in a cost-effective way*. In other words, if we cannot choose the 'correct' amount of pollution to clean up, at least we should clean up the amount we *do* choose at the lowest possible cost.

While this has obvious appeal as a policy rule, is it not subject to the same dilemma as before, namely the difficulties of obtaining information about the control costs of the various pollution sources (firms or plants)? The answer, surprisingly enough, is no. Economists have shown, at least in principle, that if the policy instrument is designed correctly, firms themselves will behave in such a way as to achieve a cost-effective allocation of abatement.

Two policy instruments are commonly proposed that have this property. The first is an **emissions tax**, paid for every unit of pollution. To see how it results in cost-effective pollution reduction, imagine the imposition of an arbitrary tax rate, T, such that every unit abated by each of the two firms represents a tax payment of T saved by the firm. Wherever the control cost lies below T, that firm will choose to abate that unit. If, on the other hand, the cost of abating the unit is greater than the tax, it is profitable for the firm to pay the tax rather than take the more expensive option of reducing its emissions by one more unit. For any tax rate, marginal control costs for each firm will be equal to T and cost-effective pollution reduction will occur without the environmental authority having to make complicated and perhaps inaccurate assessments of control costs at different emission sources. The firms emitting the pollution do the work.[9]

The second instrument is a system of **tradeable emissions permits**. Under such a scheme, an overall level of permissible pollution, $\hat{Q}$, measured in units of emissions, is decided upon. In order to be legally allowed (entitled) to pollute, firms must obtain permits (or vouchers), each of which entitles them to emit a given number of units of pollution. For a firm to pollute more than its allocation of permits allows, it must acquire more. This is why it becomes important that the permits can be traded—at any point, firms can choose between using a given permit, or selling that permit to another firm and incurring the abatement cost instead (or buying another permit and abating less).

The key limitation on this process is that the total number of permits produced just allows for the amount of permissible pollution $\hat{Q}$ which has been chosen. So, legally, firms are restricted to emit, in total, the amount $\hat{Q}$.

How do we establish that such a scheme satisfies the cost-effectiveness criterion? Imagine an allocation of permits such that, if each plant was to simply use up its own allocation, plant 2's control cost for the final unit exceeded plant 1's. Given this, plant 2 would actually be willing to buy another permit from plant 1 at any price below 2's marginal control cost. Plant 1 would sell a permit at any price above its own marginal control cost. In fact, *whenever* the marginal control costs are unequal, there is scope for trade in permits that will effectively reduce the total cost of emissions.[10]

The lesson in this is that the use of economic (price-based) signals can play a useful role in not only achieving reductions in pollution, but also in economising on the *costs* of achieving that reduction. This becomes important when we compare conventional approaches to pollution policy to the suggested economic approaches. The standard 'model' of a pollution policy is some variant on the command-and-control method, which involves developing some standard (for example, an acceptable amount of emissions of an air particulate, measured in parts per billion) which is then imposed on every individual source of the emissions within the relevant jurisdiction. It has already been argued that an arbitrary 'equal abatement' rule tends to violate the principle of cost-effective abatement.[11]

To conclude this section, it is probably fair to say that one of the greatest contributions economics can make to issues of pollution policy is to highlight how market-based mechanisms can generate the appropriate incentives for polluters to achieve given pollution reductions in a cost-effective manner. This economises on the information that public regulators need to collect.

A key analytic difference between the emissions and tradeable permits schemes lies in the fact that regulators will often not know what level of tax will result in what level of emissions reduction. By contrast, the permit system *defines* a set level of reduction. (The tax system implicitly provides information on marginal control costs, though.) The two schemes will also differ in the way they respond to changes in the supply or demand of the good (and thus changes in damage and/or control costs). Also the two schemes have different implications for when regulators are not confident of the true control and damage costs, yet have to implement a scheme and live with it.[12]

However, as was indicated earlier in this section, the problem of finding the 'optimal' level of pollution reduction (Q^* in Figure 2) still requires major and difficult data collection by a public authority. More generally, for an economist to offer advice on the possible trade-offs involved between, for example, building a dam which will dramatically alter a wilderness area, and leaving the area intact but foregoing the power which would be provided, an economist would require data both on the physical and the value implications of each alternative. This is the subject of the next section.

4.2 *Environmental Valuation—Uses and Problems*

Debates about environmental matters often involve a conflict between goods traded in markets which have explicit (price) valuations attached to them, and environmental assets or amenities, the values of which are not directly reflected in a market. When contemplating the use of a hardwood forest stand, we would have a reasonably good idea of its worth as wood products. However, we are likely to have much less accurate knowledge of its worth *in situ* (in its natural state), in which it may have various valuable roles (as part of a water catchment; as a shelter for wildlife; as an absorber of CO_2; as an aesthetically pleasing area in and of itself).

In Section 2, we discussed the comparison of costs and benefits which is at the heart of normative economics. For one alternative action—chopping down the trees—we have values as revealed by the market. That 'the market' is willing to pay a given amount for the wood from those trees represents a valuation as placed by society on the wood value of the trees. How can this valuation be compared to the value of the trees left intact? We would ideally like to produce some comparable number, or range of numbers, which can be directly compared with the market valuation. Such number(s) would need to be expressed in similar units to the market values, such as dollars, in order to enable the comparison.

As noted in the Introduction, this approach is sometimes criticised for 'commodifying' nature. The standard rebuttal to this involves a simple piece of logic: if we treat any part of nature as being 'beyond price', then we have implicitly assigned an *infinite* value to it. If infinite values are assigned to all of nature, none of it could *ever* be changed in *any* way. The fact that humans do utilise parts of nature to our own ends, as do animals and insects, is a reflection of the fact that we do recognise trade-offs between enjoying nature as we receive it, and enjoying it for what we can do with it; both of which can contribute to our quality of life. In doing so, humanity assigns at least some parts of nature a *finite* value.

The task, then, is to estimate these finite values as accurately as possible, in terms of '**willingnesses to pay**' (WTPs) for environmental assets, to compare with the WTPs revealed by the market for their use in the production of goods and services. These values in alternative uses will then typically be compared in the form of a **cost–benefit analysis**, the result of which provides information as to the losses and gains society can expect from alternative actions. Our interest in this section will be on how to ascertain these non-market valuations.

There is a variety of procedures, all with their own strengths and weaknesses. The main differences between the various methods boil down to the following distinctions:

(i) Do they elucidate 'use values' only, or 'non-use values' also?

(ii) Do they rely on observed 'market-like' data (revealed preferences) or 'expressed' data (hypothetical preferences)?

These two questions are related, but should be thought about separately.

The distinction between use and non-use values for environmental valuation hinges on the possibility that people may themselves make distinctions between valuing an environmental amenity for the use they may be able to make of it (such as camping in a national park), or even for the possibility of being able to do so, as opposed to placing a value on the pure *existence* of the amenity in question. The total economic value attributable to that amenity is then just the sum of the use and non-use values. Ideally, methods of estimating environmental value will provide reliable information on both the use and non-use aspects. In practice this is difficult, as shall be shown.

One reason for the difficulty is that some methods for imputing values to environmental amenities rely on drawing inferences from observed behaviour. As such, they reflect use values, in the sense that the numbers generated represent WTPs for the use of a particular environmental asset or amenity. These 'revealed preference' methods will be discussed first, and then the major 'expressed preference' method (which can, in principle, handle non-use values) will be discussed.

The first technique is the **Travel Cost Method** (TCM), typically used to assess the benefits attached to a recreational site. As the name suggests, the TCM involves treating the costs of travel to a recreational site as data from which 'environmental preferences' can be inferred. For example, carloads of backpackers planning to bushwalk a particular trail will be interviewed or surveyed on arrival at the site, with data being collected on their point of origin, their mode of travel, their income,[13] and other variables. It is important to realise that the aim is to determine *all* the relevant travel costs, not just the cash costs of items like petrol or entry fees to the site. These might include costs of babysitting or home security, unpaid time away from paid employment, perhaps the value of time used in the travelling itself,[14] and so on.

Using these data, a demand curve can be constructed for visits to the site, expressing how many visits to the site one would expect to see for a given 'entry fee' equivalent. In turn, this demand curve can be used to generate a societal WTP for the environmental amenity under examination.

Another widely used approach is known as **Hedonic Pricing**. The idea here is to take a price paid for a good or service, and isolate an 'environmental' component from that. The standard example is the price paid for a house. Obviously, a number of things will affect the price the house fetches in the market, including the location of the land, the quality of the building, and the quality of the environmental amenities associated with the house. (For example, the analyst might be interested in the value attached to a nearby park, or to the average cleanliness of the air in the neighbourhood.) To estimate the premium the house attracted due to the relative cleanliness of the air, say, the analyst would need data on a number of house prices, including ones with similar locations, buildings etc. The idea is to isolate as much as possible the environmental aspect (air quality) and compare how changes in air quality affect house prices. By doing so, a WTP for clean air can be established.

Difficulties in using the Hedonic Price approach involve the complexities of collecting the data and adjusting it for the other attributes, such as 'building quality' (age? size? materials used?), or the importance of location (distance to shops? public transport? a town centre?), and so on. Only by judiciously accounting for these other differences can the difference in property prices due to differences in environmental amenities be imputed with accuracy.

The final technique to be discussed here differs from the two above in that it uses expressed preferences rather than revealed ones: as such, it has the potential benefit of being able to incorporate non-use as well as use values. However, revealed preference methods do have the advantage of being visibly rooted in 'reality', in the sense that they derive from peoples' actual behaviour. But before discussing such disadvantages of expressed preference methods, we need to outline the principal method itself.

Many potential environmental assets or amenities do not easily lend themselves to travel cost or hedonic pricing studies. How should analysts assign values to these assets if such values cannot be imputed from actual behaviour? If people do place a value on such assets, how is it to be uncovered? One answer is, 'Ask them!'. That is, seek to directly ascertain a WTP from persons who have a stake in the environmental issue at hand (air quality, beach cleanliness, nuclear safety, endangered species preservation). Various methods of asking respondents to provide quantitative valuations of environmental assets are collectively given the label of the **Contingent Value Method** (CVM). In practice, there are a number of ways of asking the relevant questions, and there is evidence that the answers provided are sensitive to the way in which the questions are asked—making the questionnaire design an important consideration.

For example, it matters how the environmental amenity is 'framed' in the questionnaire. If it is a wilderness area in which a development is proposed, how many similar areas are there in the region, state or country? Are there endangered species at risk, and what genetic information may be lost, or what other changes to the ecosystem might occur, if that species dies out? If the proposed development is likely to damage the area, how extensive is the damage expected to be? Is there a small possibility of catastrophic damage?

Furthermore, how are the valuation questions presented to the respondent? For a wilderness area, the key question may be something like 'If an entrance fee was charged for entry into this area, what is the maximum you would be willing to pay to enter it?'. Alternatively the question may seek to elicit an annual tax payment that the respondent would pay to prevent a development going ahead in the area. (Note the emphasis on use value implied by the former.)

Also, the question will often not seek to allow the respondent to nominate a single amount: instead, a series of bids may be proposed, with the respondent signalling yes or no to each. For example, in the tax question, the respondent may be offered (hypothetical) 'tax' payments, usually presented as an increase in the tax they pay under the current system, such as $20 per annum, $50 per annum, etc., with the questionnaire continuing until a negative answer is reached.

The fact that different ways of presenting the questions can influence the outcome is an important concern. An even more pressing concern to some, known as strategic bias, is due to the hypothetical nature of the payments being solicited. Someone very opposed to a development going ahead has an incentive to state a WTP greater than an amount they would be willing (and able!) to pay in practice.[15] Because the CVM has had widespread application, some of them concerning high profile and politically sensitive issues, the plethora of directions from which it can be criticised has led to no small amount of controversy.

Perhaps the most notorious CVM study was done in the wake of the 1989 oil spill from the *Exxon Valdez* tanker in Alaska. In this case—an incident involving the deaths of many thousands of birds and animals, though with no real threat of extinction—the study involved over one thousand respondents from across the United States (in an attempt to focus on non-use values, Alaska was excluded). The question of valuation was framed around WTPs for a proposed system of escort ships through Prince William Sound where the spill occurred, which would contain any future spills. Respondents were asked to vote on whether they would support the system at prices given by the questioner.

In summary, the preferred estimate for the median WTP was $31 per household.[16] Extrapolating this figure over all households in the United States generates a figure of between two and three billion dollars. This was an enormously sensitive issue for Exxon, as the result could be used as the basis for a damages claim should they be found liable. There was much debate about the validity of the method and results,[17] with the result that a panel of distinguished economists was established to investigate the validity of using CVM to ascertain non-use values for environmental damage claims. The panel gave CVM a provisional thumbs-up, although they suggested a series of guidelines for future CVM applications.

A similarly controversial CVM study in Australia will be discussed in the following section. Meanwhile, further discussions of the techniques of environmental valuation in general can be found in Hodge (1995), Pearce, Markandya and Barbier (1989), and Pearce and Turner (1990).

5. Policy Issues and Applications

5.1 Some Local Applications

Two local applications will serve to demonstrate the possible roles that economics and economists can play in shedding light on major environmental issues, and influencing—or *not* influencing—the policy process. Both examples discussed in this section relate to environmental valuation—that is, comparing the value of an *in situ* environmental asset to the economic value generated by a development proposal.

The first of these examples is the proposed Gordon-below-Franklin dam, which was proposed during the 1970s as a scheme to supply Tasmania with increased hydroelectric power, and also create jobs in a state beset by unemployment.[18]

The issue became something of a litmus test for the environment/development debate, not to mention one of the most politically divisive issues of the time, inspiring protests and counter-protests, and being a pivotal episode in the formation of Green political parties in Australia. Amidst all this sound and fury, however, economists did perform a cost-benefit study of the proposal, weighing up the potential benefits of increased (and hence cheaper) electricity supply with the potential loss of extensive (albeit secluded) wilderness.[19]

The chief difficulty was that there were no obvious ways of determining use values for the wilderness through methods like hedonic pricing or the TCM, due to the relative inaccessibility of the area. Instead, the analysts employed an argument based on *irreversibility*—how big would the benefits of the dam have to be to justify losing the wilderness area *forever*? Or, since the benefits of the dam had already been estimated, how large would the benefits associated with the wilderness area *now* have to be to make it worth foregoing the increased supply of hydroelectric power? Based on this approach, the conclusion came out that the economic case for building the dam was weak.

A more recent example is the proposal to mine gold at Coronation Hill, adjacent to the Kakadu National Park. Circumstances differed considerably from the previous case. Green issues had increasingly become part of the mainstream political agenda in the intervening period, to the extent that the then government had established the Resources Assessment Commission (RAC) to evaluate and advise on contentious environmental issues. Also, the mining proposal was coming from the private sector rather than, as in the Tasmanian case, from a state government.

The RAC was charged with evaluating the environmental costs of the proposed development. In one regard, there was a similarity to the Tasmanian dam case: calculating use values associated with park visitors seemed likely to generate quite low figures for the area's aggregate valuation. Thus, the RAC went beyond consideration of use values only, and undertook a major CVM study concerning the Coronation Hill area, with eminent international figures in the CVM area acting as consultants (see Imber, Stevenson & Wilks 1991).[20] The result was a figure for preservation benefits that far outweighed any possible benefits from the development, even though the likely extent of environmental damage associated with the mining operation would have been far less dramatic than in the dam case. (In the study, the RAC actually used two scenarios, major impact and minor impact. In both cases, they found WTPs to avoid the damage high enough to recommend against development.)

In the Tasmanian dam case, the economists' study was a sideshow relative to the political controversy. In the case of Coronation Hill, the RAC CVM study engendered a controversy all of its own. Economists sceptical of CVM, pro-development figures and a number of politicians and commentators all criticised the RAC study and found fault with its conclusions. The very magnitude of the benefits found by the RAC led many to talk of the respondents playing with 'funny money': that is, hypothetical payments that no one would ever have to actually make. However, it should be noted that even were the estimated benefits *substantially lower*, they would still outweigh the benefits of going ahead with the development.

At one level, the cost–benefit studies in each case had seemingly little impact on the final outcome. In both cases, decisions were made against the developments, but not on obviously economic grounds. In the dam case, the decision rode on a High Court case fought on the grounds of State versus Federal government rights to make key decisions when international treaties might be at issue. In the Coronation Hill case, the final decision was attributed to preservation of aboriginal sites rather than the likelihood of the social costs of development exceeding the benefits. It is a question for readers to consider, whether it is preferable that decisions are made according to legal and political criteria such as these, or whether better decisions would be made on average if they were made explicitly on the grounds of cost–benefit analyses.

Finally, as has been mentioned, the Tasmanian dam case was a pivotal episode in Australian environmental politics. The RAC study arguably had its own long-run effect: the RAC was abolished a few years later by the government that had established it.

5.2 An International Application—The Greenhouse Effect

Local environmental problems have local political and economic dimensions. The 'social' costs and benefits are almost always viewed from the national perspective. Final policy decisions on environmental matters are made generally through national institutions such as parliaments and courts. However, many of the prominent environmental problems of recent years have been in the international sphere, and there arises a host of new political and logistical issues. One major example is the **enhanced greenhouse effect**, which refers to the increase in mean global temperatures that is expected to result from humanity's emissions of 'greenhouse gases' (carbon, methane etc.).

If significant global warming occurs, there is a range of possible impacts it will have on humans (not to mention other species).[21] Yet, the physical relationships involved are so complex that there is much potential for disagreement about which effects are likely to occur, and even about what the impact on average temperatures will actually be. So, at the very least the situation involves major uncertainty.

Furthermore, the scale of the greenhouse effect forces us to confront something that has been glossed over until now: as well as considering the magnitude of the gains and losses to society, we need to think about *who* is incurring the gains and losses. Global warming has international dimensions—that is, gains and losses will vary by country, even by region—and it also has an *intergenerational* dimension—where gains and losses may be felt by people not yet born, and whose preferences will almost certainly not be taken into account through any market mechanism.

Economists' research and advisory efforts on global warming fall into the areas of both environmental valuation—determining the 'optimal' level of greenhouse gas emissions as per Figure 2—and of cost-effective abatement mechanisms. The first of these can be thought of in terms of an *optimal response to the prospect of global warming*, in that the response might take the form of (combinations of) reduction of emissions, adjustment to the effects of warming, and so on. In that way, the optimal theoretical response would involve equating marginal costs of abatement of each greenhouse gas at each source,[22] which should also be equal to the marginal cost of adjustment to climate change. (If it costs less to adjust, we should adjust rather than abate.)

This would be a logistical nightmare to orchestrate, even if all the appropriate information about the magnitude and effects of warming was available. Thus economists tend to build simpler aggregated models which (necessarily!) utilise simplifying assumptions about both the scientific impacts and the economic consequences of various actions. In particular, they tend to assume least cost reduction of emissions. The important point to note here is that different analysts produce quite different recommendations, depending upon the specification of the model.[23] For example, it is hard to factor into a model the possibility of potentially catastrophic outcomes (such as the sea level rising so high as to flood inhabited areas, with significant loss of life).

In thinking about the second aspect—reducing greenhouse gas emissions in a cost-effective way—economists have offered advice that looks familiar from Section 4.1. Proposals for both an internationally applied carbon tax, and a system of internationally tradeable emissions permits in greenhouse gas, have been discussed. Each has important implications with regard to both cost-effectiveness and the distribution of costs and benefits.[24]

Both schemes would require major and ongoing international cooperation; and potentially large transfers of income between different nations may be involved. The political hurdles to be jumped so as to implement and successfully enforce such a scheme are considerable. (It is evidently contentious enough for governments to undertake action on domestic environmental issues when highly visible economic costs are at stake; for many governments to agree on effective multilateral action is harder again.)

As already indicated, uncertainty about climate change and its impacts is another overriding difficulty in framing policy on this issue. Generally, there are two schools of thought on how to respond to the large degree of doubt about what climate change might mean, each one advocating caution about the 'opposite' thing. The first school calls on the 'precautionary principle',[25] which says in the face of possible major damage, it is prudent to act as though one expects the worst. That is, emissions should be reduced until and unless we find out that we do not need to. This view is advocated in Alden (1995). The second school, arising from the work of Dixit and Pindyck (1994), counsels caution about incurring unnecessary abatement costs, and views the possibility of 'keeping one's options open' as an option that is valuable in itself when uncertainty is prevalent (noting that the costs of abatement are far less uncertain than the benefits).[26]

Finally, recall that large-scale issues such as global warming will have intergenerational effects, causing costs (and possibly benefits) to future generations, as will reducing emissions of greenhouse gases. The issue of intergenerational equity (fairness) is too complex to discuss here, but readers should note that most discussions involving time in economics—including the cost–benefit analyses outlined earlier—will feature the phenomenon of *discounting the future*. This is essentially the opposite of the process of compound interest; to understand why economists conventionally employ it, and the controversies surrounding it, readers should consult any standard book on environmental economics or cost–benefit analysis.

The nature of the global warming problem—that it is global, and involves large-scale phenomena over long periods of time—brings us to the final section, where we briefly discuss the linkages between economic growth and the environment.

5.3 *Growth and the Environment*

Public concerns that the natural environment would be subject to overwhelming pressures, up to some point of 'collapse', as a result of economic (and/or population) growth dates back at least as far as the writings of Parson Thomas Malthus, around the end of the 18th century, who argued in print that the growth of population would increase faster than the growth in agricultural output, leading eventually to famine and the 'collapse' to a bare subsistence economy. With the benefit of hindsight, we can see that Malthus was wrong both about the increase in agricultural productivity (which has been enormous) and the (in)sensitivity of population growth to income growth.

However, Malthusian concerns continue to resurface. In particular, the early 1970s saw the publication of the so-called Club Of Rome (COR) report, 'The Limits to Growth', which was basically an exercise in forecasting trends in resource use, population growth etc., performed by prominent American academics using a methodology they christened 'systems dynamics'. The grim message of this exercise, given much currency in the media of the day, was that 'overshoot and collapse' was inevitable, *given* the continuation of current trends. Finding more resources, for example, would only delay the inevitable, not prevent it.

Economists were particularly critical of this work. The assumption that current trends in consumption, population, resource use and so on would continue in the future as in the past was, in their view, exactly the thing generating the COR's conclusion; and it was exactly that assumption which needed to be subjected to scrutiny. Not only does resource use change over time, generally in response to market forces that reflect their relative availability, but there is little evidence that exhaustible resources are becoming worryingly scarce in an *economic* sense. New ore discoveries, new technologies, new recycling possibilities, and other 'conservationist' reactions to the market signals of increasing resource scarcity, all present problems for the COR conclusions.[27]

However, in the previous section, we identified the possibility that, even if we do not face the prospect of a dire shortage of tin, we may face the prospect of major harmful climatic effects. In other words, while we may be sanguine about the possibility that we will 'run out of things', there is a danger of overloading the planet with pollution and perhaps causing catastrophe and 'collapse' that way.

But does economic growth itself cause pollution? Put another way, is higher pollution always a consequence of increased economic growth? The link seems less straightforward than that. Even when the former USSR had become economically fairly stagnant, it was a heavy polluter. (In some ways, the USSR's centralised system provided even less incentive for producers to avoid pollution than did the Western market-based system.) Pollution can be prevalent in less developed countries; problems such as land degradation often arise more from poverty than through surplus production. Richer countries, it is argued, will value cleaner environments more highly, and can afford to divert some resources into cleaning them up, relative to poorer countries. This hypothesis gets some empirical support in the work of Grossman and Krueger (1995), who investigate a 'hump-shaped' relationship between per capita GDP and levels of various pollutants.

6. Conclusion

The lesson to be learned from this investigation of the role of economics in environmental issues is that, from the side of positive economics, *incentives* matter. To understand why pollution occurs, and which ways may be more or less successful in tackling it; to understand patterns of resource use and substitutability; to understand the interaction between a whole range of government policies and their environmental impacts, a proper understanding of the underlying incentives—how people perceive the costs and benefits of particular actions, and how they react to them—is crucial.

From the side of normative economics comes the conclusion that making *any* judgement, any social choice, about environmental matters implies a valuation of the environmental asset or amenity concerned, and that economics can help explicitly codify a system of valuation—costs and benefits aggregated over society—to assist in public decision making.

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Endnotes

1. See, for example, Jacobs (1994).

2. Such as markets, referendums, courts and governments.

3. It is a moral truism that the ends do not *always* justify the means. However most of the means we are concerned with are not *that* bad!

4. See Schmid (1995).

5. This is a cause–effect proposition: *If* we impose such a tax, *then* there will be less driving and thus fewer emissions in total—holding all other variables constant. Of course, there may be other side-effects flowing from a given action which will need to be examined also. For example, if there are differential rates of tax, or even exemptions, for certain classes of vehicle, then we would expect this to affect people's behaviour as they try to avoid the tax.

6. For simplicity, we will focus on one general category of market failure. For more detailed discussions of market failures, see earlier essays in this series (for example, King 1993; Alden 1995) or a standard introductory economics textbook.

7. There are caveats to this reasoning. If the seller misrepresents the quality of the good to the buyer, or if the buyer changes their mind later about what they really wanted, this may not hold. But, such examples notwithstanding, the idea is clear. Voluntary trade is mutually rewarding.

8. There is an important perspective which we only have space to mention in passing here. *If* the victims of pollution have effective legal recourse, and *if* they can mobilise themselves to act in a coordinated fashion, they could approach the polluting parties and strike a bargain of their own, that is, to be compensated according to their suffering. Alternatively, if their legal recourse is weak, they could bribe the polluters to reduce their pollution emissions. Either of these actions will 'internalise the externality', in that the polluter will now be mindful of its external costs—costs to third parties—and will change its behaviour accordingly because such behaviour is now being punished or rewarded. This simple but powerful argument is due to Ronald Coase (1960), who later won a Nobel Prize, partly for this insight. Like the invisible hand argument, of which it is a restatement, the key debates revolve around how important its *limitations* are. If such bargaining is feasible, the invisible hand may function adequately; if not, other policy actions, to be considered in the next section, may be required.

9. One problem, therefore, with using the tax system for pollution control is that without knowledge of the control costs, it will not be clear how big a reduction in pollution will be achieved for any given tax rate!

10. A more detailed exposition of the cost-effectiveness criterion is available in Chapter 12 of Tietenberg (1994). Readers should be aware of the potential importance of this criterion. At the national level, the difference between cost-effective pollution reduction, and inefficiently expensive reduction, could be quite substantial in terms of incomes and jobs.

11. In fact, the command-and-control form of regulation can lead to quite perverse outcomes.

Blinder (1987, ch. 5) discusses amendments to the Clean Air Act in the United States involving legally mandated abatement technologies. New electrical power plants were required to install an expensive and unreliable technology (smokestack scrubbers) designed to reduce sulfur dioxide emissions, while existing plants could comply by simply burning cleaner fuels. This gave the existing plants a cost advantage, reducing the business that would have gone to the newer plants, and thus reducing the investment in newer, cleaner plants. Then, when the scrubbers broke down, untreated emissions from the new plants flowed directly into the air. So, not only was no regard paid to the cost-effectiveness of pollution reduction, it is not clear how successful the policy was in reducing emissions at all.

12. These issues are discussed in Tietenberg (1994, p. 224). Other difficulties in translating theory into practice are discussed in Baumol (1991). Discussions about the use of these anti-pollution policies in practice are contained in Smith (1993) and Tietenberg (1994, ch. 13).

13. Income may relate both to their ability to afford the travel, and perhaps the income foregone in undertaking the travel.

14. This is somewhat controversial, given that it could be argued that the travelling is itself part of the recreational experience.

15. Some critics go further and argue that any discussion of biases, whether they are unconscious biases due to the questioning, or conscious biases arising from strategic concerns, implies that there exists a 'true' value from which the biased values diverge. They then dispute that there are in fact unambiguous, underlying true values for WTPs because people do not treat the environment as a commodity to be 'paid for' like a marketable good. This is taken up in Jacobs (1994).

16. Of the third of respondents who chose not to vote for the system at the prices offered, one-third of them gave the reason that they thought the oil companies should pay. This raises issues related to those raised in the previous endnote.

17. See, for example, the Symposium in the *Journal of Economic Perspectives* (1994). A number of participants in the CVM debate were engaged as expert witnesses for or against Exxon in the court case.

18. For our purposes, the extra power generated by the dam is the *economic* benefit of the project; while the jobs created in the process may be regarded as a *political* benefit, in a cost–benefit analysis the labour used to build the dam and supply the power enters on the *cost* side of the ledger, not as a benefit. This may seem strange—in everyday terms, creating jobs always seems like a *good* thing—but to explain why economists treat matters this way would take more space than we have here. Interested readers should consult a text in cost–benefit analysis.

19. The study is presented in Saddler, Bennett, Reynolds and Smith (1980), with a summary provided in Chapter 7 of the book by Pearce (1983).

20. Richard Carson, the key consultant, was also involved with the *Exxon-Valdez* CVM study.

21. These include a rise in sea levels due to increased melting of ice sheets and/or thermal expansion of the oceans; major geographical shifts in agricultural productivity; possible loss of species which cannot migrate or adapt to climate change; impacts on water supplies, and so on.

22. Strictly speaking, each gas should also be weighted by its respective contribution to temperature increase.

23. A summary of some results is contained in Chapter 11 of Hodge (1995).

24. See the discussions in Pearce and Turner (1990) and Common (1995).

25. This is sometimes framed as, 'If we act as though it matters and it doesn't matter, it doesn't matter. If we act as though it doesn't matter and it does matter, it does matter'.

26. In this case, the precautionary principle is effectively restated as 'If we act as though it does matter and it doesn't matter, it *does* matter. We have incurred costs we could have avoided'.

27. Common (1995) contains an even-handed discussion of the COR's work.

References

Alden, D. 1995, 'Can economics help take the heat out of global warming?', *Australian Economic Review*, 1st quarter, pp. 130–42.

Baumol, W. 1991, 'Toward enhancement of the contribution of theory to environmental policy', *Environmental and Resource Economics*, vol. 1, no. 4, pp. 333–52.

Blinder, A. 1987, *Hard Heads, Soft Hearts: Tough-Minded Economics for a Just Society*, Addison-Wesley, Beverly, Massachusetts.

Coase, R. 1960, 'The problem of social cost', *Journal of Law and Economics*, vol. 3, pp. 1–44.

Common, M. 1995, *Sustainability and Policy*, Cambridge University Press, Melbourne.

Dixit, A. & Pindyck, R. 1994, *Investment under Uncertainty*, Princeton University Press, Princeton, New Jersey.

Grossman, G. & Krueger, A. 1995, 'Economic growth and the environment', *Quarterly Journal of Economics*, vol. 110, no. 2, pp. 353–78.

Hodge, I. 1995, *Environmental Economics: Individual Incentives and Public Choices*, Macmillan, Hampshire.

Imber, D., Stevenson, G. & Wilks, L. 1991, *A Contingent Valuation Survey of the Kakadu Conservation Zone*, Resource Assessment Commission Research Paper no. 3, AGPS, Canberra.

Jacobs, M. 1994, 'The limits to neoclassicism: Towards an institutional environmental economics', in *Social Theory and the Global Environment*, eds M. Redclift & T. Benton, Routledge, London.

Journal of Economic Perspectives 1994, Symposium on Contingent Valuation, vol. 8, no. 4, pp. 3–64.

King, S. P. 1993, 'Microeconomics for Year 12', *Australian Economic Review*, 1st quarter, pp. 76–88.

Pearce, D. 1983, *Cost–Benefit Analysis*, 2nd edn, Macmillan, Hampshire.

Pearce, D., Markandya, A. & Barbier, E. 1989, *Blueprint for a Green Economy*, Earthscan, London.

Pearce, D. & Turner, R. K. 1990, *Economics of Natural Resources and the Environment*, Harvester Wheatsheaf, Hemel Hempstead.

Saddler, H., Bennett, J., Reynolds, I. & Smith, B. 1980, *Public Choice in Tasmania*, Australian National University Press, Canberra.

Schmalensee, R. 1993, 'Symposium on global climate change', *Journal of Economic Perspectives*, vol. 7, no. 4, pp. 3–10.

Schmid, A. A. 1995, 'The environment and property right issues', in *Handbook of Environmental Economics*, ed. D. W. Bromley, Blackwell, Bristol.

Smith, B. 1993, 'Natural resource use and environmental policy', in *Economic Rationalism: Dead End or Way Forward?*, eds S. King & P. Lloyd, Allen & Unwin, St Leonards.

Tietenberg, T. 1994, *Environmental Economics and Policy*, Harper Collins, New York.