LECTURE 8

Neoclassical Analysis of Pollution Costs

A Brief Account of Some Neoclassical Analysis.

The typical neoclassical analysis of the costs of pollution and of the means of controlling it are well represented by the text of Pearce and Turner (1990).

The analysis can be conveyed via a diagram (Figure 1.) which shows the marginal social costs of pollution and the marginal private benefits accruing to the polluting manufacturer. More generally, we might consider two parties M and V who impose costs on each other through their separate activities. {The letters are chosen for convenience, and you might think of a mnemonic: M: the manufacturer, V: the victim.} For simplicity, we may imagine that direct costs arise solely from M's activity, the level of which is the value of the variable x.

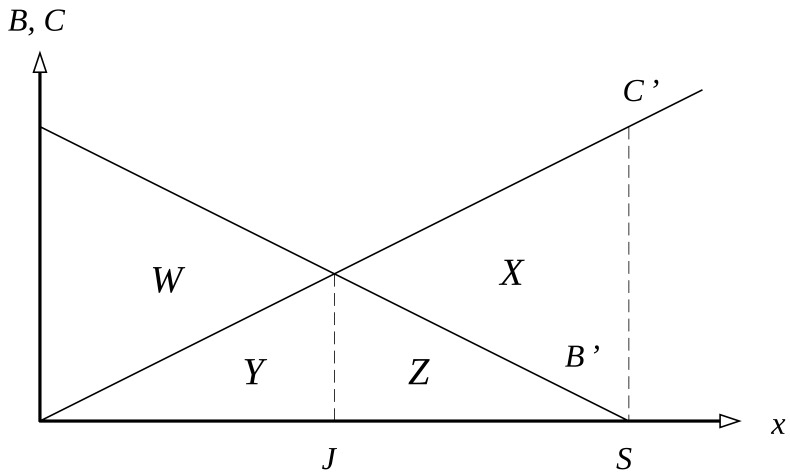

Figure 1. The benefits and costs of a polluting activity. The function $B'(x)$ describes M's marginal benefits and the function $C'(x)$ describes V's marginal damages which are nuisance costs resulting from M's activity.

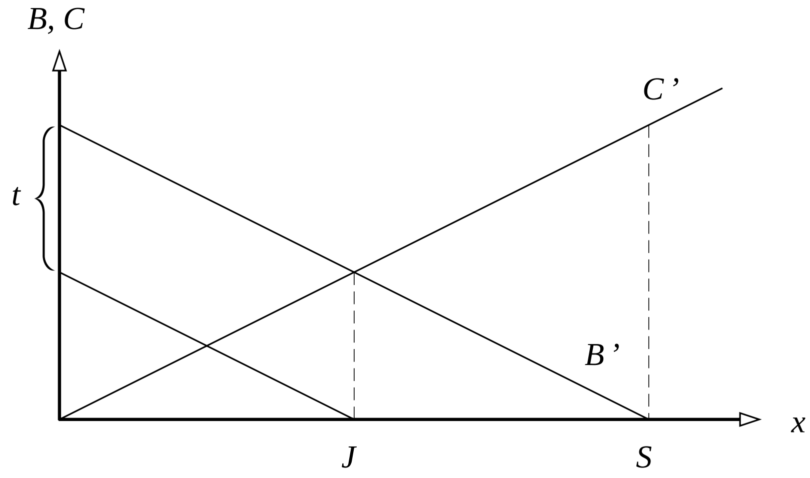

Figure 2. A Pigovian tax at the rate of t per unit of production would induce M to reduce the level of output from $x = S$ to $x = J$, which is the level where M's marginal benefits are equal to the marginal damages from pollution.

Observe that the diagram is essentially atemporal, and it seems to imply that the pollution damages cease when the level of the activity is reduced to $x = 0$. However, there may be lingering damage associated with the activity in the past. We can add a temporal dimension by using the device of discounting. In that case, $C'(x)$ would comprise all of the (marginal) costs ensuing from the present activity summarised in a present value. This is not to imply that costs from the activity conducted in the past will not accrue; we have simply attributed these to a previous accounting period. In the economist's phraseology, "Bygones are bygones."

In these terms, it is clear to an economist that the optimum level of the activity in question is where $x = J$, which is where $C'(x) = B'(x)$, which is to say that marginal costs equal marginal benefits; and, associated with this level of activity, there is an "optimal level of pollution."

However, if M has an unhindered right to conduct his activity, then his profit-maximising output will be at the level $x = S > J$. Conversely, if M has to seek a licence from V to allow him to conduct his activity, and if V is totally intolerant of M's nuisance, then the solution would be $x = 0$.

Doubtless, M and his economic adviser would tell V that he was misguided in prohibiting M's activity, and that a mutually beneficial bargain could be struck which would allow M to produce at $x = J$ whilst paying V a compensation of Y at least. The compensation could be more than this since M's net benefit from the activity is $W + Y$.

This, of course, is an unusual case. More often, M can do as he pleases and V must seek redress by encouraging M to produce less than S. If V were able to bargain freely, then he would encourage him to produce at the level J by offering him Z at least, since these are the net profits which M would have to forego in reducing his activity level from S to J. By striking this bargain, V would be saving himself a total of $X + Z$ in nuisance costs.

If V is unable to bargain directly with M, then he might subscribe to *Friends of the Earth,* or spend his Saturday mornings in the surgery of his local MP; and, at length, he might convince the government to use a tax to limit M's noxious activity. In the trade of economics, such device is called a *Pigovian tax,* in recognition of its original proponent Pigou, (1912), (1920). Here, we are envisaging tax of t per unit of output which reduces the marginal benefit of M. If the tax rate t is determined appropriately, then the outcome should be to reduce the level of M's activity to $x = J$, whilst yielding a tax revenue of $T = t \times J$. This is shown in Figure 2. It should be observed that a Pigovian tax that is tied to the number of units manufactured by M is liable to be relatively straightforward to administer.

There are definitions of a Pigovian tax, which are sometimes advanced by the proponents of the Coase Theorem, that differ from the one used above and which seem to be wilful misinterpretations. The tax is interpreted to mean a levy imposed on M which is equal to the full cost imposed upon V by the noxious process, at whatever level it happens to be conducted. If, for example, the activity level were at S, then this cost would correspond to the area $Y + Z + X$ in Figure 1, whereas, if the activity were conducted at level J, then the cost would correspond to the area Y. It is clear that the imposition of a fixed levy would not cause M to vary the level of activity unless it led to its complete cessation on the grounds that it had become unprofitable.

The situation would be different if the levy were designed to be varied *pro rata* with the level of activity; but, even then, it might not achieve the desired objective, which is to constrain M to operate at $x = J$. To succeed in this, the level of t would have to be judged precisely. From elementary principles of economics, it is clear that it is the marginal cost of pollution that should be charged, which varies with the level of output. In practice, however, it is difficult to determine a marginal cost.

The Theorem of Coase

Observe that we have proposed three scenarios, all of which should result in the same optimal level of output but which differ in their implication regarding the distribution of income.

The assertion of Coase (1960) is that it is a matter of indifference whether the activity level J is achieved via scenario I or scenario II, in which either M or V are solely in possession of the property rights, but he was averse to any attempt to achieve it via the third scenario which entails taxation or some other regulatory intervention. He admitted that practical difficulties may prevent J from materialising, but he was quite sanguine about the probability of this outcome when a free-enterprise economy is allowed to operate untrammelled by the impositions of government regulation. We can take issue with him on two accounts:

First, we may not agree that—according to the Hicks–Kaldor criterion—the economist is justified in ignoring the matter of the distribution of the costs and benefits amongst the parties. It is often the case that those who suffer from the noxious effects of a manufacturing process are amongst the most disadvantageous members of society. Their incomes may be low and they may have little to spend on ameliorating the circumstances in which they are constrained to live. We might be unwilling to accept the judgment, implicit in the argument of Coase, that the scale of their suffering is proportional to the level of their incomes.

Secondly, we might be very skeptical about the possibility that V, whom we envisage as a disparate and disorganised party, will be able to bargain effectively with M. In the jargon of economics, V's transaction costs might exceed the value of the marginal damage imposed by M's nuisance at all levels of output that lie between the optimum level and the actual level of M's production. That is to say, V's transaction costs in attempting to drive the level of output from S down to J might exceed $X + Z$ in Figure 1, which is the cost of the nuisance that V seeks to avoid.

The reaction of a neoclassical economist to such circumstances as these might be to declare that, if it were not efficient for V to strike a bargain which would alleviate M's nuisance, then, by that very token, production must be taking place at an optimum level. However, to assert this would be to utter a mere tautology which follows from the premise that the only economically acceptable outcomes are those which result from unfettered free enterprise. A very different conclusion might emerge if one were prepared to admit that the inability of V to seek redress might be a symptom of the kind of market failure which calls for public intervention.

The Problem of Free Riding

Part of the problem that can arise when V is a diffuse collection of agents is due to so-called hazard of *free-riding.* Some individuals amongst V will wish to profit from a bargain struck with M without participating in the costly process of achieving it. They will argue to themselves that their own contributions, small as they are, are unlikely to affect the outcome. Therefore they are disinclined to pay the contributions; and, if enough of the agents in V are so-minded, then the party will be unable to negotiate with M.

The problem of free-riding arises when V is seeking some redress from M. Another problem can arise when M has to seek the agreement of each member of V to be allowed to conduct the activity. In that case, some members of

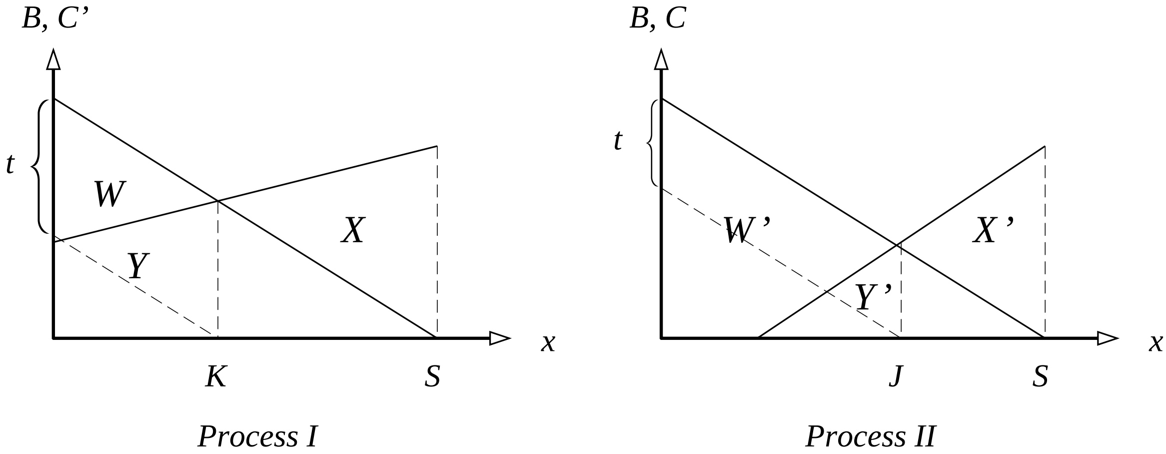

Figure 3. The social optimum would be achieved not by operating Process I and level K but, instead, by operating Process II at level J.

V may recognise that they are in a position to hold M to ransom. They will recognise that, insofar as V's activity remains profitable, there is a possibility of capturing more of these profits than the amount which is attributable to the cost which it imposes upon them personally. If enough of the agents in V are so-minded, then M will be unable to strike a profitable bargain, and the enterprise will not be undertaken.

Refinements of The Critique

Sometimes an analysis is called for that is more subtle than the foregoing account. Let us imagine that two processes are available to the manufacturer, which are depicted in Figure 3. If there were no constraints on the manufacturer's activities, then he would operate process I at the level of $x = S$. Observe, moreover, that, if $X > W$ (as in the diagram) which is to say that that the cost of the damages exceeds the private benefits of M's activity, then it would be better from a social point of view if the manufacturer were prevented altogether from operating the process if this were the only alternative to his operating at S.

A further feature of our analysis is that the social optimum would be achieved not by operating process I at level K—as one might suppose—but, instead, by operating process II at level J; for the reason that $W'-X' > W-X$, which is to say that the net social benefit from process II exceeds the benefit from process I.

The question arises of how we might induce the a manufacturer to move to J. Let us content ourselves with making the observation that a Pigovian tax might not achieve this end. For, if it happens that $W + Y - T$—the total private profits from I—is greater than $W' + Y' - T'$—their private profits from II—then the manufacturer will remain at K. What this implies is that the tax policy would have to be buttressed by a further inducement or regulation leading to the adoption of II. The problem is that the Pigovian tax varies *pro rata* with the level of output rather than with the level of pollution.

The Options Facing the Regulator

Let us now imagine that, for whatever reasons, the Government, or one of its regulatory agencies, feel bound to intervene to control pollution. An environmental agency usually has several means of controlling pollution which might induce M to move from S to J. These include the following:

(1) Exhortation and persuasion,

(2) Quantitative and qualitative controls on emissions, which are essentially commands,

(3) Taxes on pollution inputs, eg. a tax on coal based on its sulphur content,

(4) Taxes on emissions,

(5) Pigovian product taxes coupled with subsidiary inducements, if necessary,

(6) Subsidies on pollution reductions (subsides in aid of purchasing abatement equipment),

(7) A system of tradable pollution permits,

(8) A system of tradable input permits.

A producer who wishes reduce its emissions can pursue the following options:

(a) Reduce the output level. Eg. a coal-fired power station can reduce its sulphur dioxide emission at the cost of reducing its electrical output.

(b) Change the production process or alter the mix of inputs. Eg. the power station can change to a low-sulphur coal or eventually to gas or to nuclear.

(c) Apply abatement equipment to existing technology. Eg. the coal-fired power station can install a sulphur scrubber in its chimneys.

We shall assume that the producer always finds the method of lowest cost for abating their pollution, which may involve a combination of all of the above. On the assumption that the costs of abatement vary continuously with its extent, we can afford to ignore the precise details of how it is achieved.

Pollution Taxes

We have already discussed the Pigovian product taxes, which are item (5) on the list, and we have pointed to some of their potential defects. In particular,

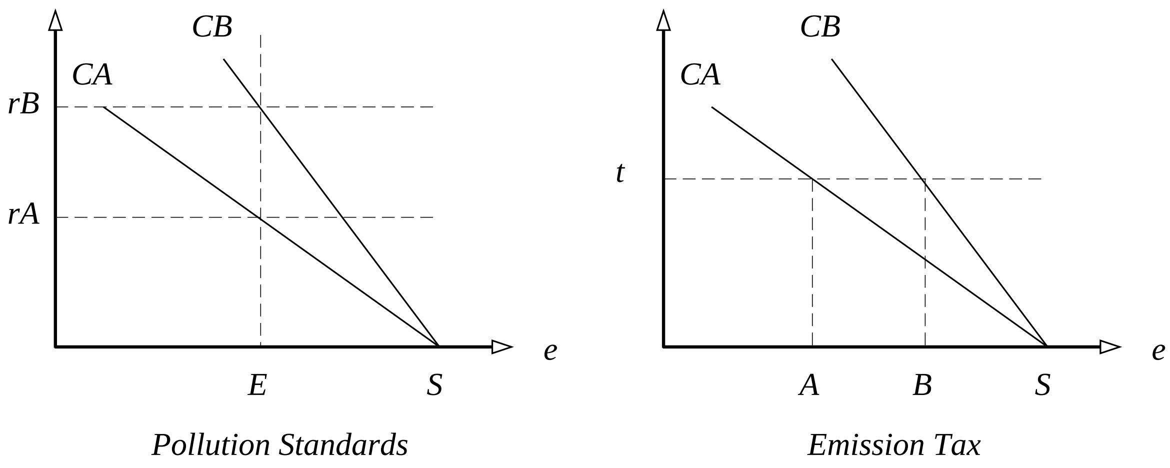

Figure 4. The unequal marginal costs of pollution abatement in two firms. On the left, are the costs entailed in meeting an emissions standard of E units of pollution. On the right, are the differing responses of the two firms to a tax of t per unit of pollution. The social optimum would be achieved by allowing all firms in the industry to equate their marginal costs of abatement to the level t of an appropriate emissions tax.

they fail to stimulate the responses under (b) and (c). Therefore, we should now consider an alternative taxation scheme that is tied to the quantity of the pollutant emitted by a manufacturer, which is item (4) of the list above. We shall widen the discussion to include an entire industry composed of a variety of manufacturers operating with differing costs structures.

One is bound to assume that the costs of achieving a given level of pollution abatement vary across firms in an industry. According to the proposition of Baumol and Oates (1971), (1988), an overall level of pollution abatement throughout the industry will be achieved at minimum cost when the marginal costs of abatement are the same in every firm. They assert that this can be achieved by imposing a tax uniformly across the industry which is charged on the basis of the units of pollution emitted. It has to be conceded, however, that such a tax is liable to be far more difficult to administer than a simple Pigovian tax based on the number of units of a manufactured product. It is often difficult to measure the pollution accurately.

This proposition concerns a situation in which only the overall level of pollution matters and where the question of the local intensity of pollution does not arise. Then the proposition is virtually self-evident, and it implies that the largest reductions of pollution should be accomplished by the firms

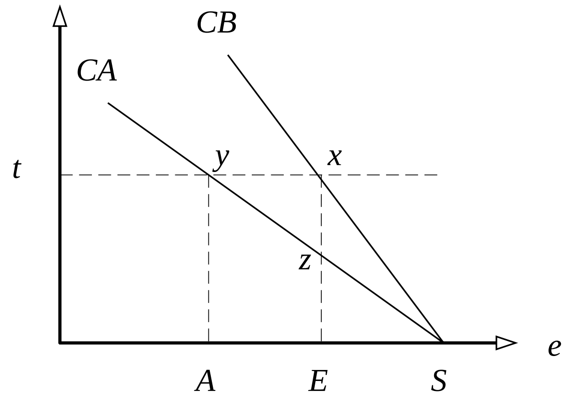

Figure 5. Savings under innovation with a pollution tax.

for which it is least costly to reduce pollution. The logic is illustrated in the Figure 4.

The figure shows two curves CA and CB which represent the marginal costs of pollution abatement for two firms within the same industry. The curves rise from the point S of zero abatement, and the extent of abatement is measured as the distance from S toward the origin. The origin corresponds to complete pollution abatement. In order to compare like with like, it is has been imagined that, in the absence of abatements, the extent of pollution is the same amount S for both firms.

One can imagine that the regulatory authority will tolerate a quantity of pollution equal to $2E$ and that it imposes on both firms to limit their respective pollution to E. The marginal cost of abatement incurred in meeting the standard rises to rA for the first firm and to the higher level rB for the second firm. It is clear that it would be beneficial to the firms if, in meeting the overall pollution constraint of $2E$, firm B were allowed to reduce its pollution by less than E and if, in compensation, firm A were to reduce its pollution by more. In that case, the firms could come to some mutually beneficial arrangement.

The question that remains is how to achieve this outcome. The answer which is presently proposed is to impose a tax of t per unit of pollution to be paid by both manufactures. They will adjust to this regime by setting their levels of pollution at A and B respectively; and, if the taxation rate has been fixed appropriately, the total quantity of pollution will be $A + B = 2E$, which is the intended amount.

A further advantage that can be claimed for such pollution taxes is that they tend strongly to encourage the adoption of new technology which limits pollution. The matter can be illustrated by Figure 5, which compares, for a single manufacturer, the incentives under a regime that imposes pollution standards that are costly to meet with those of a regime of pollution taxation. The curve marked CB show the marginal costs of abatement using old technology, whereas the curve marked CA shows the lesser costs of the new technology.

Under the standards regime, which constrains the manufacturer to emit no more than E units of pollution, the new technology will result in a social saving of (xzS). Under such a regime, there is no incentive for the manufacturer to do more than achieve the minimum standard. Under a regime of pollution taxes, if it were to adopt the new technology, the firm would reduce its emission from E to A, and there would be a net social saving of $(yxS) > (xzS)$. There is a strong incentive for the manufacturer to adopt the new technology, since it will enable a reduction from $t \times E$ to $t \times A$ of the tax bill that is associated with pollution.

Problems with Pollution Taxes

There are several potential problems associated with pollution taxes that can be identified. In the first place, It may be very difficult to determine an appropriate level of taxes, even when it is only the overall level of pollution that is subject to control, such as in the case of a uniformly mixing pollutant. Moreover, the suggestion that the level could be found by iteration, i.e. by trial and error, is flawed. The wrong initial level might lead to a situation where producers are locked into inappropriate technologies.

The assumption of uniform mixing might be inappropriate. If local intensities of pollution are to be taken into account, then differential taxation may be called for, which could be impractical.

Finally, the cost of pollution might not be well defined. There might be thresholds of pollution intensity beyond which the damage would be irreversible. If pollution endures through time, then the problem of inter temporal comparisons will arise.

Marketable Pollution Permits

The idea of marketable pollution permits was introduced by Dales (1968). It is based on three propositions:

(i) Taxes are anathema,

(ii) It is difficult for the regulator to know enough about the cost structure in the industry to set the right level of taxes,

(iii) It is inappropriate to impose a uniform product tax upon the industry when different manufacturers face different costs in controlling pollution.

The purpose of marketable permits is to control the total amount of the pollution which is generated by an specific industry. The regulatory authority is to issue permits for this amount, but the permits are to be freely tradable on an open market. It is proposed that this should allow pollution to be regulated at the least cost. Those who are capable of controlling pollution inexpensively will sell their permits to those who find it costly to control.

The idea is a attractive one, but is has several flaws. The main problem is that it imposes no control on the local intensity of pollution. In fact, it seems to be designed to generate hot spots of pollution. For it enables a heavy polluter to acquire an inordinate number of permits which can allow excessive damage to be inflicted. Some pollutants, which are quite tolerable in small quantities, become seriously damaging when certain thresholds of concentration are exceeded. The only way of preventing the thresholds from being surpassed is to enact legislative prohibitions which need to be buttressed by a system of inspection and a system of penalties.

References

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

Baumol, W., and W. Oates, (1988), *The Theory of Environmental Policy—2nd Edition,* Cambridge University Press. Cambridge

Cheung, Steven N. S., (1973), “The Fable of the Bees: An Economic Investigation,” *Journal of Law and Economics.* XVI 11–33.

Coase, R.H., (1960), The Problem of Social Cost, *Journal of Law and Economics’* 3, 1–44 .

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

Friedman, D., (1989),*The Machinery of Freedom, 2nd Edition.,* Open Court: La Salle, Chapters 41–43.

Johnson, David B., (1973), “Meade, Bees, and Externalities,” *Journal of Law and Economics,* XVI, 35–52.

Meade, J. E., (1952), “External Economies and Diseconomies in a Competitive Situation,” *Economic Journal,* 54.

Pearce, D.W. and R.K. Turner, (1990), Economics of Natural Resources and the Environment, London: Harvester Wheatsheaf.

Pigou, A.C., (1912), *Wealth and Welfare.*

Pigou, A.C., (1920), *The Economics of Welfare,* Macmillan, London.

Posner, R., (1986), *Economic Analysis of Law, 3rd Edition.,* Little Brown & Co. Boston .