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Efficiency in pollution control in the short and long runs: a system of rental emission permits

ROBERT A. COLLINGE / *University of Maryland*
WALLACE E. OATES / *Bureau of Business and Economic Research and University of Maryland*

While a Pigouvian tax on waste emissions equal to marginal social damage (MSD) can sustain an efficient pattern of emissions among existing polluters in the short run, the recent literature on externalities stresses that this is not, in general, sufficient to ensure efficiency in the long run (see Rose-Ackerman, 1973; Gould, 1977; and Burrows, 1979). Economic efficiency over both the short and long runs makes two demands on polluting firms (Schulze and d'Arge, 1974): (1) the marginal value of the firm's output must equal marginal cost (including any external, as well as private, costs); (2) the total value of the firm's output must not be less than total cost (where again costs include both private and external costs).

The Pigouvian tax ensures the satisfaction of the first (short-run) condition for economic efficiency. Assuming that the prices of other inputs reflect accurately their social opportunity costs and that firms are price takers, a tax on waste emissions equal to MSD 'internalizes' the social cost of waste emissions and leads the profit-maximizing firm to produce where price equals (social) marginal cost. All this is well understood.

However, the recent literature points out that policy measures to correct the allocative distortions associated with externalities must also satisfy a 'total' or 'exit-entry' condition: the firm's net contribution to social welfare

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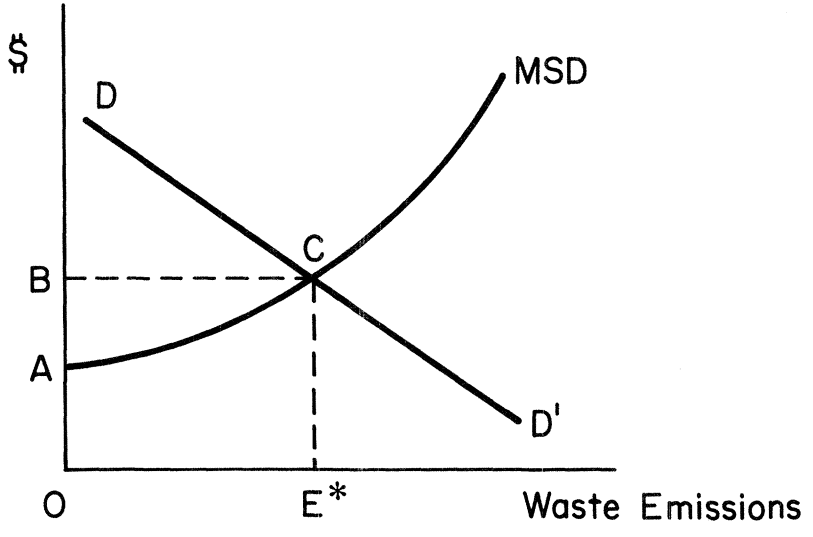

FIGURE 1

must be non-negative.[1] The Pigouvian tax will not satisfy this condition in instances where marginal social damages are not constant over the relevant range.[2] This discovery has led to some pessimistic judgments: "Thus we have the interesting conclusion that none of the 'practicable' instruments moves the system to a Pareto optimum when the marginal damage cost curves slope upwards" (Burrows, 1979, 500).

Our purpose in this paper is to describe a system of marketable emission permits that can, in quite a straightforward way, rectify matters. As we show in the second section, a system of rental emission permits (REP) can satisfy both the short-run and entry-exit conditions, even where marginal social damages vary with the polluting firm's level of emissions. In the first section we briefly review the nature of the problem.

THE ENTRY-EXIT ISSUE

The nature of the entry-exit problem is easily seen in terms of figure 1. Suppose that we have a region in which there is a single polluter. The MSD curve depicts the marginal social damages associated with the polluting firm's

1 This condition also applies to the short run; the firm should engage in production only if the value of its output exceeds total variable costs.

2 Carlton and Loury (1980) contend that the Pigouvian tax fails even where MSD are constant. We have shown elsewhere (Oates and Collinge, 1981), however, that their treatment involves a misspecification of the Pigouvian tax. Properly understood, we contend that the Pigouvian tax is not subject to their objection.

emissions, while DD' is the firm's demand curve for waste emissions.[3] The optimal level of emissions is E^*. A Pigouvian levy consisting of a unit tax on emissions equal to OB will induce the firm to emit the socially desired quantity of wastes. The difficulty is that the firm's total tax bill, $OBCE^*$, will exceed the total damages that its emissions impose on society ($OACE^*$) by the amount ABC. The total levy is thus excessive and in the long run may force the firm to leave the industry, even though its output has a net positive value to society. In the case where the MSD curve is downward-sloping, the opposite is obviously the case: the firm's total tax bill will understate the damages of its emissions and therefore may induce entry (or discourage exit) where the firm's total costs to society exceed the value of its output.

We thus find that where the MSD curve is not horizontal, a Pigouvian tax equal to MSD will not, in general, satisfy our long-run, entry-exit condition for efficient resource allocation. The tax itself will induce a distortion in the vector of final outputs with too little output in industries confronting upward-sloping MSD curves and excessive outputs in those with downward-sloping marginal damage functions. What is needed is a schedule of taxes reflecting the changing level of MSD with successive units of emission.[4] This last point, incidentally, suggests that we could regard this particular objection to Pigouvian taxation as largely a semantic one. As Burrows points out, the problem arises if we interpret the Pigouvian tax "as a *fixed-rate* charge per unit of effluent emission equal to the marginal damage at the Pareto optimum" (1979, 495). One could easily argue, however, that in the context of a rising or falling MSD curve, the spirit of the Pigouvian prescription of a unit tax equal to MSD implies a schedule of taxes.

However one is inclined on the semantic issue, the point remains that a non-horizontal MSD curve complicates greatly the administrative feasibility of a Pigouvian fee. The problem may not appear to be too serious in terms of the case we have examined in this section; we could envision, for example, the environmental agency confronting our single polluter with a schedule of effluent fees, where the marginal fee varies over successive units of emissions. But what about cases of more than one source of pollution? As Rose-Ackerman notes, 'With a large number of dischargers this solution is not possible since there is no unambiguous way of allocating total damage among polluters' (1973, 515). Some type of determination would seem to be necessary as to which polluter is entitled to which 'stretch' of the tax

3 We treat waste emissions as a factor input so that DD' is the value of the marginal product of emissions. Note that for any point on the horizontal axis the vertical distance to DD' is also the firm's marginal abatement cost.

4 Alternatively, the environmental authority could supplement the Pigouvian tax on emissions with a fixed-sum subsidy (or levy) on entry. In terms of figure 1. the unit tax on emissions of OB would be accompanied by a subsidy to the firm of ABC so that the total tax bill (net of the subsidy) would equal total damages. Were the MSD curve downward-sloping, the supplementary measure would be a fixed-sum tax. We doubt, however, that this alternative approach has much appeal at the policy level.

schedule. We describe in the next section a system of rental emission permits that can resolve this problem; the system satisfies both the short-run and entry-exit conditions for economic efficiency in cases of one, several, or many polluters.

A SYSTEM OF RENTAL EMISSION PERMITS (REP)

Our basic problem is to design a system that confronts each polluter with a charge at the margin equal to MSD and with a total payment equal to the total damages that its emissions impose. We begin by describing the mechanics of a system of rental emission permits (REP) and then explore how it achieves these two objectives. We assume throughout that the pollution damage function is convex.

Implementation of the REP system proceeds as follows.

Step 1. Print permits, each allowing emission of some designated quantity of pollutant over some interval of time (e.g., one ton of sulfur per month).

Step 2. Number these permits and order them sequentially ($i = 1, \ldots, \text{I}$).

Step 3. Attach a rental price (R_i) to each permit, i, equal to the marginal social damage that would be caused by the quantity of emissions specified (E_i) on the permit, given that all permits with smaller numbers were being fully utilized. The rental payment per emission right would thus vary directly with the permit number; for a permit numbered 'θ,' the rental price would be:

$$R_\theta = C\left(\sum_{i=1}^{\theta} E_i\right) - C\left(\sum_{i=1}^{\theta-1} E_i\right),$$

where $C(\cdot)$ is the total damage (or social cost) function.

Step 4. Distribute these permits (by any of several methods to be discussed later), subject to a rental payment of R_i to be paid each time period until the permit is returned. Following the initial distribution of permits, any unclaimed permits would be available without an *initial* charge to anyone willing to make the rental payment associated with the particular permit.

Step 5. Allow firms to buy and sell these permits, with each transaction registered with the environmental authority.

This procedure effectively generates a supply curve of emission rights approximately equal to MSD (labelled S_{REP} in figure 2).

We turn next to the properties of the REP system for our three cases of one, many, or a 'few' sources of pollution. If there is only a single polluter, that polluter will face a marginal cost of pollution that approximates the true marginal social damage function. This occurs because the polluter (a

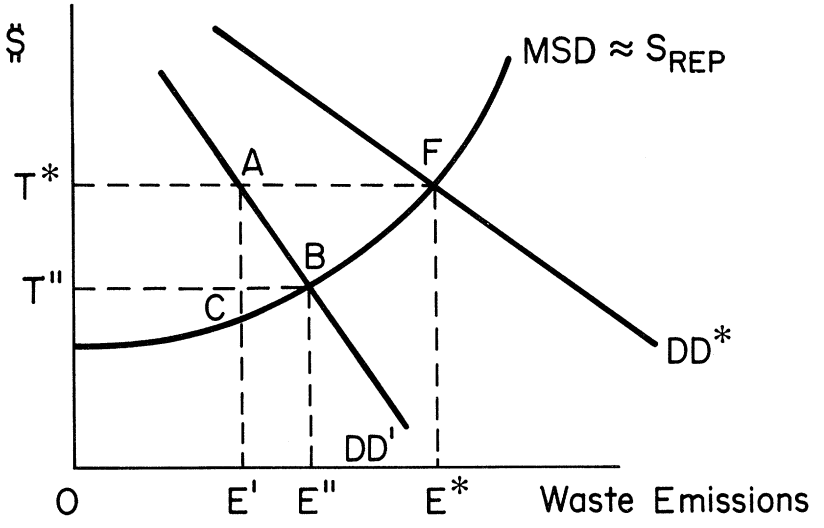

FIGURE 2

monopsonist in this case) will select permits with the lowest possible rental price (R_i) per unit of emission. Our first-order condition is thus satisfied, since the monopsonist will equate the marginal cost of permits (the supply schedule) with the value of his marginal product. Likewise, this procedure satisfies the entry-exit condition: the total cost of the permits to the polluter is equal to the sum of the incremental damages (i.e., the total damages) he imposes on society.

The REP system works equally well for the case of many 'small' polluters where the marginal social damages are (approximately) constant over the range of emissions of any single source. In this case the unit cost of holding emission rights should equal the Pigouvian tax rate. This is just what occurs, since a resale market for permits would develop. A competitive market would generate a single, market-clearing price for emission rights equal to the Pigouvian tax rate (T^*). The price of any particular REP, θ, would be:

$$P_\theta = (T^* \cdot E_\theta) - R_\theta.$$

Although not necessary for the efficiency of our proposal, the life of permits could (and presumably would) extend over many (N) periods. In this case, the market price of a permit θ in the current period would become:

$$P_\theta = \sum_{t=1}^{N} [(T_t^* \cdot E_{\theta t}) - R_{\theta t}]/(1 + r)^t,$$

where r is the market rate of discount and T^* is the expected value of the

Pigouvian tax rate in period t. The REP system thus satisfies both the first-order and entry-exit conditions in a 'competitive world' (i.e., where the firm's level of emissions does not affect the level of marginal social damages).[5]

The third case is one of a 'few' polluters: where there exists more than one source but where at least one polluting firm is of sufficient size that MSD varies significantly over the range of its emissions. We depict this case in figure 2. Let DD^* represent the total demand for emission rights from all j sources in the region. Suppose that the jth source is a 'significant' polluter. The curve DD' is the aggregate demand of the remaining $(j-1)$ sources: $DD' = DD^* - DD^j$. The optimal quantity of emissions is E^* with OE' having as its source firms $1, \ldots, j-1$, and $E'E^*$ coming from firm j.

It is evident from figure 2 that source j imposes two types of costs on society: the external damages associated with an increase in total waste emissions in the region (i.e., the area $E''BFE^*$) and a cost on other sources in the region equal to $E'ABE''$.[6] The latter cost element represents the opportunity cost associated with the transfer of emission rights to firm j from other firms in the region; it is the increase in abatement costs that these other firms are forced to bear in order to accommodate the emissions of the jth source.[7] Both these cost elements should enter the calculations of polluter j, and under the REP system they will. This is easiest to see in the case where source j is a new entrant into the region. Before the advent of j, the equilibrium level of waste emissions is E'' with marginal abatement costs equal to T''. The new equilibrium following the entry of source j will find j laying claim to the rental permits corresponding to the emissions over the range E'' to E^* and purchasing permits for $E'E''$ from existing sources. The area $E'CFE^*$ (equal to MSD) indicates the rental payment that source j must make for its emissions, and the area ABC is the payment that j must make to other firms to induce them to part with the permits for emissions $E'E''$. Since area ABC is also the social opportunity cost of transferring emissions from sources $1, 2, \ldots, j-1$ to any other source, we find that a 'significant' polluter will both equate marginal abatement cost to MSD and make a total payment equal to the sum of the damages its emissions impose on society and the opportunity cost of the emissions to other sources.[8] In this way both the short- and long-run efficiency conditions are met.

5 The many-period formulation of the REP system allows some room for speculative activity that may be the source of inefficiency. A slightly more complex formulation of the system can avoid this. See Collinge (1981, 3).

6 Since any particular polluter under consideration is, in a sense, 'marginal,' we associate the damages from its emissions with the stretch of the MSD curve to the right of the total emissions of other sources.

7 This particular cost element seems to have escaped notice in earlier studies (e.g., Burrows, 1979).

8 Source j may, of course, hold or purchase permits other than those corresponding to the range $E'E^*$. However, as noted in the text, the price of any permit will equal $(T^* \cdot E_\theta - R_\theta)$ so that the effective cost of all permits is, in equilibrium, the same.

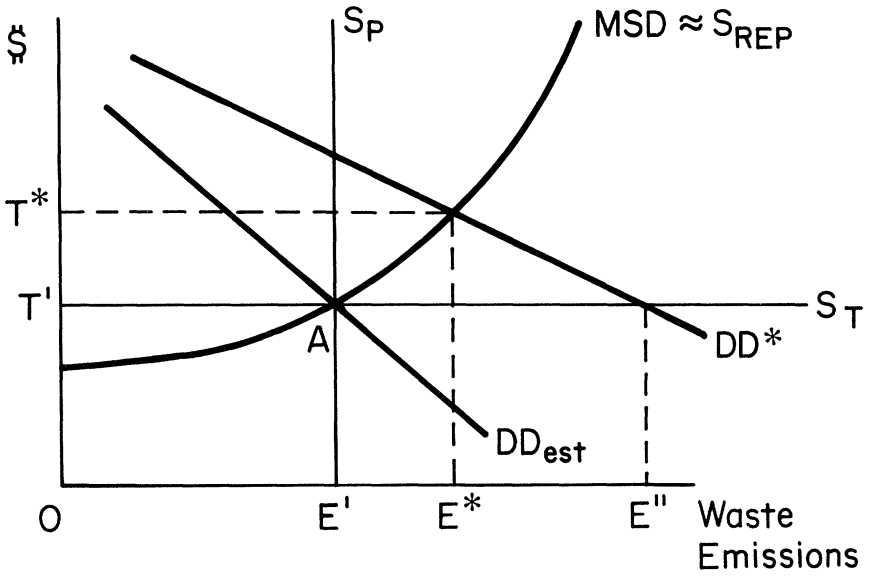

FIGURE 3

ON INFORMATIONAL ECONOMIES

The REP system thus satisfies both conditions for the efficient control of externalities for the cases of one, many, or a few polluters. We would stress, in addition, that REP achieves these objectives while making *relatively* modest informational demands on the environmental authority. In particular, the administering agency need have no knowledge whatsoever of firms' demands for emission rights (i.e., of marginal abatement costs). The REP system effectively confronts polluting firms with a schedule of prices for emissions that reflects the true social cost; the decentralized decisions of cost-minimizing polluters take matters from there with a resulting Pareto-efficient outcome. This is a very attractive property of a scheme to regulate pollution in a world where information is costly.

The standard alternative systems, a Pigouvian tax or a system of (undifferentiated) marketable permits, make much stronger informational demands. Suppose, for example, that the administering agency knows the MSD schedule but is uncertain about the levels of firms' demands for emission permits. In terms of figure 3, suppose that DD^* is the true demand for permits, while DD_{est} is the estimated demand on the part of the environmental authority. Under the Pigouvian approach the agency will set a unit tax on emissions of OT', resulting in a level of emissions of E'' (in excess of the efficient level E^*). Alternatively, under a system of marketable permits, the agency would establish a supply of E', resulting in a subefficient level of emissions.

The source of the problem is the failure of the 'supply schedule' of emission

rights to correspond to marginal social damages. A Pigouvian tax effectively results in a supply schedule which is infinitely elastic at the tax rate (see S_T in figure 3). In contrast, a system of marketable permits errs in the opposite direction: it generates a perfectly inelastic supply of emission rights (see S_P in figure 3). There is only one point (A) on either of these schedules corresponding to marginal social damage. This means that if the environmental authority, as a result of imperfect information concerning firms' abatement costs, sets the tax rate incorrectly (or alternatively, introduces the wrong number of permits), the resulting level of pollution diverges from the socially efficient level. In contrast, the REP system replicates the MSD schedule and thereby circumvents the need for any information on abatement costs.

EQUITY AND THE INITIAL ALLOCATION OF PERMITS

Step 4 of the implementation of the REP system is the initial allocation of the permits. We stress here that there are many possible ways initially to distribute the permits that are consistent with the efficiency properties of the system. Certain types of auctions of the permits, for instance, would provide an efficient source of revenue in addition to the rental payments. Alternatively, initial ownership of the permits could be conferred by lottery, perhaps on the basis of levels of emissions in some base year. The essential point is that the probability of receiving permits must not be influenced by current emission levels; otherwise, strategic behaviour by polluters can introduce inefficiencies in both short and long runs.

The initial allocation of permits certainly does have distributive implications. In particular, an initial auction of the permits to polluters places the burden upon them, not only of the costs of abatement and the rental charges associated with the permits, but also of a further one-time payment for the right to discharge emissions into the environment. Some existing studies (of non-rental permit schemes) suggest that these payments may be quite large. A RAND study (Palmer et al., 1980) of a system of undifferentiated marketable permits for the emission of certain halocarbons into the atmosphere estimates that abatement costs under the system would total about $110 million (a savings of roughly 50 per cent compared to a realistic program of mandatory controls). However, the study estimates that the cost to polluters of purchasing the permits would come to about $1,400 million – nearly seven times the level of costs of abatement![9] While these payments for the purchase of permits are simply a transfer from the perspective of society as a whole, they could represent a very sizeable cost to polluting firms.

In one sense the auctioning of permits under the REP system might appear

9 Under the REP system, the purchase price of permits under an auction would be considerably less than under a system of marketable permits with no rental payments, since polluters' willingness-to-pay for rental permits would be reduced by the current value of the future stream of rental payments. However, if the RAND study is any guide, our sense is that even after making this adjustment, the cost to polluters of the initial purchase of the permits under an auction scheme would be quite high.

to be unfair to polluters. Since in the aggregate polluters pay a sum of rents that equals the pollution damages that their emissions impose on society, the fairness of extracting further payments through an auction of the permits is questionable. Moreover, the additional cost burden to polluters of an auction could easily prove fatal to the political feasibility of such a program (see Zeckhauser, 1981). As an alternative, the environmental authority simply could allocate the permits initially among polluters free of charge. One allocation method with some appeal is a lottery. Under the lottery approach a 'fair' assignment of probabilities achieves equity in an ex ante sense. Moreover, in a sufficiently developed market, ex post equity also obtains, since each potential recipient could ensure his fair share by selling his ex ante probability for its expected cash value (or gamble, if that is his preference). Note that no moral hazard or adverse selection would exist in this insurance market.[10]

While it goes beyond the scope of this paper to explore in detail the range of possible distributive outcomes of the REP system, we conclude with the observation that the basic REP proposal allows considerable leeway in the determination of a pattern of incidence of the costs among polluters and the rest of society. The selection of a particular form of the system that is regarded as both equitable and at the same time consistent with the political feasibility of the program requires an explicit judgment from the political arena.

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10 As Rose-Ackerman (1977) points out, an initial distribution of permits to polluters without requiring their purchase provides some relief to *existing* sources; new sources, however, will have to purchase permits (or, under REP, acquire previously unissued permits with relatively high rental rates).