THE FAILURE OF THE PIGOUVIAN TAX SYSTEM

WHEN INEFFICIENCIES ARE TAKEN INTO ACCOUNT

by

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Abstract

A generally accepted theorem in environmental economics is that an emission charge is the least-cost method for society to achieve a prescribed standard. But this assumes that no inefficiencies with respect to the undesired outputs occur at the level of the firm. However, in the real world firms do not operate efficiently, because of existing regulations, differences in availability of resources (e.g. management), and the adjustment costs involved if there are quasi-fixed inputs. Therefore, the proposition that taxes are the least-cost method to achieve a prescribed standard can be challenged.

1. Introduction

One of the central concerns in environmental economics is to design reasonably cost-effective policies to control externalities. The fiscal and/or legislative instruments that can be used to attain standards serving as targets for environmental quality are evaluated. Under certain conditions taxes (and also marketable permits) turn out to be the least-cost method for society to achieve a given environmental goal (e.g. Baumol and Oates, 1988; Pearce and Turner, 1990). The most important conditions required for this theorem to be valid are: (i) firms seek to minimize the private cost of producing outputs, (ii) no inefficiencies with respect to the undesired outputs occur at the level of the firm, and (iii) the production function is concave. This well-known theorem has been the subject of many empirical studies (for an overview see Tietenberg, 1990) which have compared the difference between the cost of a control and command system with the least-cost method. The excess costs of a control and command system turn out to be very large, the general conclusion is that the use of economic incentives should be promoted.

In environmental economics it is a generally accepted theorem that a charge on emission is the least-cost method for society to achieve a prescribed standard. Various authors have commented on the conditions required for this theorem and doubts are raised with respect to the empirical studies that claim to support the theorems validity. The concavity of the production function has been challenged by Baumol and Oates (1988). Baumol (1991) argues that the empirical studies overestimate the cost savings offered by a system of fees, because they use linear programming but in reality the costs of environmental programmes are distinctly nonlinear. Taking the actual trading process into account Atkinson and Tietenberg (1991) show that the cost savings of marketable permits are much smaller than the cost-effective allocation suggests.

In this paper the second assumption (that there are no inefficiencies in undesired outputs at the level of the firm) is investigated. Inefficiency has been a neglected topic in the analysis of charges, because empirical studies have always started from a normative approach. The use of linear programming models implies that charges work ideally. No allowances are made for inefficiencies. However, in practice many inefficiencies can occur with respect to the undesired outputs; an overview is presented in Section 2. The consequence of these inefficiencies is analysed in Section 3, where it is shown that taxes are no longer the least-cost method to attain a prescribed environmental standard[1]. Conclusions are drawn in Section 4.

2. Inefficiencies at the firm level

In the literature on economic efficiency, efficiency is broken down into two multiplicative components: technical efficiency and allocative efficiency. Technical efficiency is defined as the distinction between maximum output and a given set of inputs. Technical inefficiency is mostly caused by limitations in fixed factors, such as management. A firm is allocatively efficient as long as the last unit of a resource that it employs yields as much as it would have yielded in an alternative employment (its opportunity cost). If the last unit of a resource yields less than what it would have produced elsewhere, the firm is wasteful. (Yotopoulos and Nugent, 1976: 71-77)

In this section three cases of economic inefficiency with respect to undesirable outputs will be discussed. The first case is a study in which undesirable outputs are explicitly distinguished. Sufficient data are rarely available for this, therefore two additional cases will be analysed, one where the pollutant is related to the output and one where the pollutant is related to a quasi-fixed input.

The first case relates to two studies done by Färe et al. (1989, 1992). In both studies 30 paper mills operating in the United States in 1976 were analysed. The mills use pulp, together with capital, labour and energy, to produce paper. In the process of producing the desired output of paper, undesirable pollutants are generated: biochemical oxygen demand and total suspended solids in the wastewater are increased, and sulphur oxides and particulates are emitted. These mills were operating under some environmentally-oriented regulations. In their earlier (1989) study, Färe and his colleagues measured the technical efficiency of the different mills. The mills differ in efficiency, even when undesirable outputs are taken into account. In the later

[1] A complete evaluation of the advantages and disadvantages of charges is beyond the scope of this paper. For evaluating stochastic influences, see Baumol and Oates (1988), for a treatment of other dimensions for judging policy instruments, see Bohm and Russell (1985).

study (Färe et al., 1992) they calculated the shadow prices of outputs and undesirable outputs and found large variations in the shadow prices of effluents across mills. This suggests that the regulations prevailing in this industry did not yield an efficient allocation of resources.

The second case relates to a situation where the undesired output is linearly related to a desired output (the same can be done when the undesired output is related to a variable input (e.g. fertilizer)). It is not unreasonable to assume that in the dairy-farming sector the nitrogen emission is linearly related to the output of milk. Helming et al. (1992) studied the dairy-farming sector in the Netherlands using panel data. Starting from a cost function approach and taking into account the endogeneity of the milk production they calculated the shadow prices of milk per farm. These shadow prices differ across farms: extensive dairy farms have higher shadow prices of milk than farms with very high intensive production. The latter farms have relatively more variable costs and can adjust to new production circumstances more easily. The allocative efficiency of these farms is greater than that of the extensive farms, although neither are optimal.

The third case relates to the situation where the pollutant is related to a quasi-fixed input. This input can adjust only at some cost. The presence of a quasi-fixed input is an important source of imperfect adjustment in the short-run. Durable inputs such as capital are most likely to contribute to this form of costly and slower response by producers. This idea has been formalized and analysed in adjustment cost models (e.g. Denny et al., 1981; Epstein and Denny, 1983: Lopez, 1985; Vasavada and Chambers, 1986; Thijssen, 1992). It turns out that firms partly adjust the capital stock towards the desired level. The desired capital stock is given by the long-run equilibrium, where the marginal revenue of capital is equal to the marginal cost. However, firms adjust their plans (and hence the desired level of the capital stock) every year as prices change. Another type of dynamic model is the error correction model (e.g. Gilbert, 1986). In these models the change of the quasi-fixed inputs is related to changes in the exogenous variables and the lagged discrepancy between the quasi-fixed input and the target value of the quasi-fixed input. This target value itself also depends on the exogenous variables. Because in both types of dynamic model the real capital stock never reaches the desired level, the quasi-fixed input is always allocated inefficiently. Even in dynamic models that explicitly take rational expectations into account there is divergence from the desired level (Dolado et al., 1991).

These cases can be represented algebraically. In standard theory on the evaluation of charges, the starting point is cost minimizing behaviour; see Baumol and Oates (1988: 165-169). As pointed out by Bohm and Russell (1985: 398) you can also start from a profit maximizing framework. Because quasi-fixed inputs are taken into account it is more convenient to assume that a firm is a profit-maximizer[2]. Another assumption made is that the firm maximizes the short-run profits[3]. The short-run profit function of firm h can be written as

$$\pi(p,r,w,z_h,s_h) = \max_{y,v_h} \{p\,y - r\,v_h\} - w\,z_h \qquad (1)$$

subject to the output constraint

$$F(v_h,y_h,z_h,s_h) = 0 \qquad (2)$$

where p is a vector of prices of the outputs, r is a vector of the prices of the variable inputs, w is a vector of prices of the quasi-fixed inputs, v is a vector of variable inputs, y is a vector of outputs, z is a vector of quasi-fixed inputs, s is a vector of undesired outputs, π is the short run profit function, F is an implicit function of inputs and outputs. The relation between the profit function and the pollutant depends on which of the three cases mentioned above is relevant. When the pollutant is an undesired output or linearly related to a desired output, the profit function is decreasing and concave in the pollutant. When the pollutant is related to a quasi-fixed input, the profit function is increasing and concave in the pollutant.

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[2] In a short-run cost function with a quasi-fixed input the marginal cost of the quasi-fixed input is negative.

[3] We do not start from a long-run profit function, because as pointed out some of the inputs are quasi-fixed. Dynamic models starting from maximization of the (expected) present value of profit over an infinite horizon implicitly assume short-run profit-maximizing behaviour (Thijssen, 1992).

Because of the forms of inefficiency discussed above, the marginal profit of a pollutant before an environmental policy is implemented differs across the firms[4]

$$\frac{\partial \pi(p,r,w,z_i,s_i)}{\partial s_i}_b \neq \frac{\partial \pi(p,r,w,z_j,s_j)}{\partial s_j}_b \quad i \neq j \qquad (3)$$

The suffix b refers to the situation before an environmental policy is introduced. The consequence of this divergence will be analysed in the next section.

3. The consequences of inefficiency

One of the most important propositions in the economics of pollution control is that the cost of achieving a given reduction in emissions will be minimized if and only if the marginal costs of control are equalized for all emitters. Let us begin with a simplified case which makes it possible to use illustrations. Figure 1 demonstrates the proposition. Assume that the profit function is increasing and concave in the pollutant.

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[4] In the case of the paper mills we refer to the current situation, where some kind of regulations already exist.

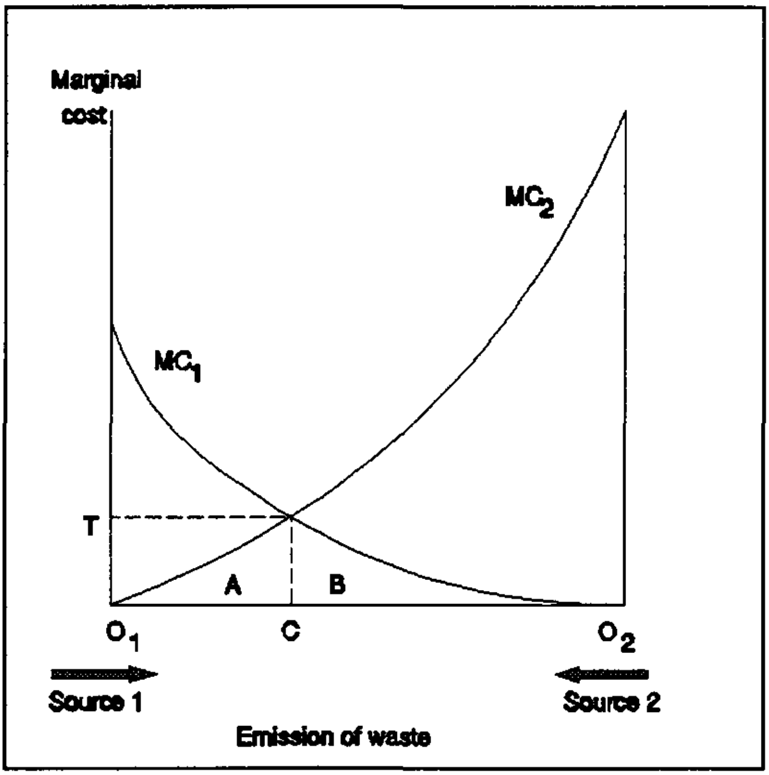

Figure 1 Efficient allocation of a pollutant (see text for explanation of symbols)

For firm 1 the quantity of emission of waste increases from left to right, for firm 2 the opposite holds. Note that, in contrast with Tietenberg (1992:371), the horizontal axis represents the amount emitted. The curves represent the marginal profit of emission, but also represent the marginal (opportunity) cost of the emission reduction. MC_1 represents the marginal cost of the emission reduction for firm 1 and MC_2 does likewise for firm 2. In the absence of an environmental policy the waste discharged by source 1 is equal to O_1O_2, and we assume that source 2 discharge the same amount (O_2O_1). Assume that the goal of the environmental policy is to halve the total waste discharged by the two sources. The length of the horizontal axis is, therefore, equivalent to the target level of waste emission, each point represents some different combination of reduction by the two sources. The total cost of a emission reduction O_2C by source 1 is equal to area B. The total cost of a emission reduction of O_1C by source 2 is equal to area A. The total cost of the emission reduction O_1O_2 by the two sources is equal to area A plus area B. At point C the allocation is cost-effective; any other allocation would result in a higher total control cost. An emission charge T on each unit of pollutant will lead to this point C, because both firms would control their emissions until the marginal control cost equalled the emission charge.

The crucial assumption here is that in the absence of an environmental policy the marginal cost of the emission of waste is equal to zero. It is assumed that in the absence of an environmental policy the emission of waste by source 1 is equal to O_1O_2. Under the same assumption the emission of waste by source 2 is equal to O_2O_1. This assumption is only valid when firms are economically efficient with respect to the emission of waste.

As discussed in Section 2 it is more realistic to assume that the marginal costs of waste are not equal to zero in the absence of an environmental policy[6]. The consequence of this divergence is depicted in Figure 2.

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[6] For most firms already some environmental restrictions are operating. In that case (e.g. the paper mills of Section 2) we analyze a further reduction of the pollutant than is implied by the current operating restrictions.

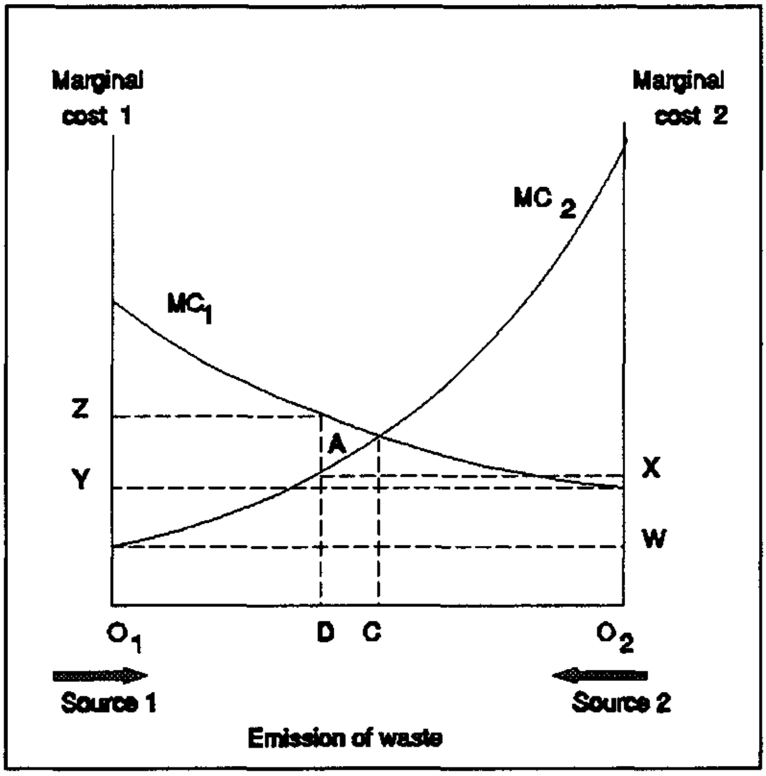

Figure 2 The costs of taxes when some of the inputs are quasi-fixed (see text for explanation of symbols)

The marginal cost of waste for source 1 is equal to O_1Y in the absence of an environmental policy. For source 2 this marginal cost is equal to O_2W. An emission charge of YZ on each pollutant from source 1 will lead to the waste discharged by source 1 being reduced by O_2D[6]. The same tax (WX is equal to YZ) will lead to the waste discharged by source 2 being reduced by O_1D. So the total reduction of the waste discharged is equal to O_1O_2, which is the goal of the environmental policy.

The uniform tax results in the desired reduction, but this policy is not cost-effective. By comparison with the least-cost policy it involves incurring additional cost (of area A). In this case regulation is even more

[6] It is even doubtful if a tax will lead to the desired reduction, because the firm is not economic efficient.

cost-effective. Halving the waste discharged by both sources will result in a point between D and C. Which policy is the most cost-effective depends on the position of the two marginal cost curves.

We will now formalize the result depicted in Figure 2. Taxing the emission by a fixed rate per unit (T) increases the marginal profit of a pollutant by this tax. So both sides of equation (3) will increase by T

$$\frac{\partial \pi(p,r,w,z_i,s_i)}{\partial s_i}\Big|_b + T \neq \frac{\partial \pi(p,r,w,z_j,s_j)}{\partial s_j}\Big|_b + T \quad i \neq j \qquad (4)$$

As can be concluded from equation (4) the marginal profit of a pollutant differs across firms after the tax T has been imposed. Therefore, charges are not the least-cost method for society to achieve a given environmental goal, when inefficiency is taken into account. Empirical research is needed to answer the following questions:

- do the marginal costs of the waste discharged by sources equal to zero in the absence of an environmental policy?
- what is the most cost-effective policy for achieving a prescribed standard: taxes or regulation?

4. Conclusions

One of the most important propositions in the economics of pollution control is that the cost of achieving a prescribed reduction in emissions will be minimized if and only if the marginal costs of control are equalized for all emitters. This leads to the well-known result that charges are the least-cost method for society to achieve a prescribed standard. However, a crucial assumption which has been made to reach this result is that the marginal costs of waste discharged are equal across firms before the charge is imposed. This is a reasonable assumption when firms work economically efficiently with respect to the undesired outputs. However, in the real world firms do not operate efficiently, because of existing regulations, differences in availability of resources (e.g. management), and adjustment costs when quasi-fixed inputs are involved. Therefore, the proposition that taxes are the least-cost method of achieving a given standard is unsound. Empirical research is needed to find out which instrument is the most cost-effective.

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