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ON THE EXISTENCE
OF AN EFFLUENT CHARGE PARADOX

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Serie B — Nr. 15

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ON THE EXISTENCE OF AN EFFLUENT CHARGE PARADOX

Alfred Endres

I. INTRODUCTION

It seems to be commonplace in economics that in a perfectly competitive equilibrium the levels of effluent generating activities are too high. Effluent charges are widely discussed in the literature as a corrective means. It is thought that the higher the effluents are charged, the more restrictive are the effluent standards met. There are, however, important cases where these plausible propositions may not be correct. BAUMOL and OATES have shown that there are problems with simple effluent charge policies, e.g., when there are several different pollutants in the economy¹⁾. PETHIG has shown that specific interrelations in the demand for goods which do or do not heavily damage the environment may make higher effluent fees lead to less restrictive effluent standards. ²⁾

In this paper, a further complication is discussed.

II. THE MODEL

To analyze the long run adjustment of a perfectly competitive industry to a change in the (per unit) effluent charge,

1) W.J. BAUMOL, W.E. OATES (1975), pp. 96-98, 185.

2) R. PETHIG (1979), pp. 117 - 137

two well known properties of the long run competitive equilibrium are used:

- a) The firms make zero profits.
- b) The firms minimize costs.

The zero profit condition leads to ³⁾

$$(1) \quad Q = p(x) \cdot x - w \cdot L - t \cdot E = 0.$$

The industry produces output x and an effluent E . There is only one input L , the price of which is w . L may be devoted to the production of output (L_x) or to activities which abate the effluent (L_a), i.e., $L = L_a + L_x$. The effluent charge is denoted t .

The amount of effluent produced is linked to output by

$$(2) \quad E = \alpha(L_a, X) \cdot X$$

Employing resources in the abatement process reduces the amount of effluent per unit of output, such that $\partial\alpha/\partial L_a < 0$. It is plausible to assume that the percentage of emissions not abated at each constant level of the abatement activity will increase with increasing output, i.e., $\partial\alpha/\partial X > 0$. It is very ambiguous, however, to make an assumption on how increasing output may affect the marginal effectiveness of the resources employed in the abatement sector, i.e., $\partial^2\alpha/\partial L_a \partial X \gtrless 0$.

3) See also W.J. BAUMOL, W.E. OATES (1975), pp. 181-187.

Given $dp, dw = 0$, equations (1) and (2) lead to

$$dQ = \left[P \cdot \frac{\partial X}{\partial L_x} + \frac{\partial P}{\partial X} \cdot \frac{\partial X}{\partial L_x} \cdot X - w - t \cdot \left(\alpha \cdot \frac{\partial X}{\partial L_x} + \frac{\partial \alpha}{\partial X} \cdot \frac{\partial X}{\partial L_x} \cdot X \right) \right] \cdot dL_x - \left(w + t \cdot \frac{\partial \alpha}{\partial L_a} \cdot X \right) \cdot dL_a - E \cdot dt = 0,$$

or, writing (b) for the term in the square bracket of the above equation,

$$(3) \quad b \cdot \frac{dL_x}{dt} - \left(w + t \cdot \frac{\partial \alpha}{\partial L_a} \cdot X \right) \cdot \frac{dL_a}{dt} = \alpha \cdot X$$

If (C) denotes the cost of employing resources in the production or abatement sector, the cost minimization condition can be stated $C = w \cdot L + t \cdot E = \min!$ for each level of output \bar{X} , or

$$Z = C + \lambda (\bar{X} - X) = \min!$$

Accordingly, the first order condition for the application of the abatement techniques is

$$(4) \quad w + t \cdot \frac{\partial \alpha}{\partial L_a} \cdot X = 0,$$

i.e., effluent charges induce firms to apply abatement techniques to an extent, which equates the marginal cost of the technique to the marginal reduction of the tax bill, caused by the technique. 3) 4)

3) See also E.J. MISHAN (1974).

4) It is assumed that the bordered Hessian of Z is negative.

Since in a perfectly competitive industry equilibrium, marginal revenue is smaller than marginal cost, the term b in equation (3) is negative. Thus, (3) and (4) directly lead to

$$(5) \quad \frac{dL_x}{dt} < 0, \text{ i.e.,}$$

an increase of the effluent charge rate will induce a decrease of industry output.

To find out about the reaction of abatement activities to taxation, equation (4) is totally differentiated, given $dw = 0$, to get

$$(6) \quad t \cdot \left(\frac{\partial^2 \alpha}{\partial L_a \partial L_x} \cdot X + \frac{\partial X}{\partial L_x} \cdot \frac{\partial \alpha}{\partial L_a} \right) \cdot \frac{dL_x}{dt} + t \cdot \frac{\partial^2 \alpha}{\partial L_a^2} \cdot X \cdot \frac{dL_a}{dt} = - \frac{\partial \alpha}{\partial L_a} \cdot X$$

It follows from (3) and (6) that the reaction of L_a to changes in t is defined by

$$(7) \quad \frac{dL_a}{dt} = \frac{\begin{array}{cc} b & \alpha \cdot X \\ t \cdot \left(\frac{\partial^2 \alpha}{\partial L_a \partial L_x} \cdot X + \frac{\partial X}{\partial L_x} \cdot \frac{\partial \alpha}{\partial L_a} \right) & - \frac{\partial \alpha}{\partial L_a} \cdot X \end{array}}{\begin{array}{cc} b & 0 \\ t \cdot \left(\frac{\partial^2 \alpha}{\partial L_a \partial L_x} \cdot X + \frac{\partial X}{\partial L_x} \cdot \frac{\partial \alpha}{\partial L_a} \right) & t \cdot \frac{\partial^2 \alpha}{\partial L_a^2} \cdot X \end{array}}$$

The denominator of (7) is negative but we cannot make a distinct statement about the numerator. Thus, we do not know, in general, how the industry will react to changes in the effluent charge, in terms of the level of abatement activities. It all depends on $(\frac{\partial^2 \alpha}{\partial L_a \partial L_x} \cdot X + \frac{\partial X}{\partial L_x} \cdot \frac{\partial \alpha}{\partial L_a})$ in (7).

This term shows the effect of a marginal increase in production inputs on the abatement inputs' marginal productivity in terms of effluent reduction, i.e., $\frac{\partial(\partial E / \partial L_a)}{\partial L_x}$.

The term would be negative if $\partial^2 \alpha / \partial L_a \partial L_x < 0$ or, $0 < \partial^2 \alpha / \partial L_a \partial L_x < - \frac{\partial X}{\partial L_x} \cdot \frac{\partial \alpha}{\partial L_a}$. The former case would indicate that employing marginally more inputs in the production process (and thereby producing a little more output) would increase the marginal (reductive) effect of the abatement activity on the effluent coefficient α . The latter case would indicate that employing marginally more L_x (and thereby increasing X) would decrease the marginal effect of L_a on α , but this tendency would be overcompensated by the fact that the abative power of L_a is applied to a higher level of output, thus allowing for a positive aggregate effect of the increase in L_x in terms of the marginal productivity of the abatement resource $\partial E / \partial L_a$.

Certainly, these cases do not contradict any equilibrium condition of the model nor are they implausible from a practical point of view.

Given that, the numerator of (7) may well be positive, allowing for a negative dL_a/dt .

To assess the consequences of these findings on the level of effluents generated by the industry, equation (2) is totally differentiated to yield

$$(8) \quad \frac{dE}{dt} = \left(\frac{\partial \alpha}{\partial x} \cdot \frac{\partial x}{\partial L_x} \cdot x + \alpha \cdot \frac{\partial X}{\partial L_x} \right) \cdot \frac{dL_x}{dt} + \frac{\partial \alpha}{\partial L_a} \cdot x \cdot \frac{dL_a}{dt}$$

Since $\partial \alpha / \partial L_a < 0$, we cannot exclude the case in which dL_a/dt is sufficiently negative to overcompensate the effect of dL_x/dt on dE/dt in (8), such that $dE/dt > 0$. Thus, it is possible that the interrelation between production and abatement processes leads to the paradox result that effluent charges cause an increase of pollution.

It should be noted that this possibility has not been generated by nonconvexities or other assumptions, complicating the traditional effluent charge model.

III. SUMMARY

A perfectly competitive polluting industry with flexible abatement technology has been analyzed. It has been shown that the industry may react to an increase in effluent

charge rates by reducing the amount of resources employed in both, production and abatement processes. This may lead to the paradox result that higher effluent charges increase the level of pollution.

REFERENCES:

- 1) W.J. BAUMOL, W.E. OATES, The Theory of Environmental Policy, Englewood Cliffs, N.J., 1975
- 2) E.J. MISHAN, What is the Optimal Level of Pollution? Journal of Political Economy, 1974, pp. 1287-1299
- 3) R. PETHIG, Umweltökonomische Allokation mit Emissionssteuern. Tübingen, 1979
(The Economics of Environmental Allocation with Emission Taxes; in German with English summary).

ABSTRACT

Alfred Endres, On the Existence of an Effluent Charge
Paradox

Effluent charges are discussed as a means for reducing pollution. In a comparative static model, the long run adjustment of a perfectly competitive industry to a change in the effluent charge rate is analyzed. The industry is assumed to have a flexible pollution abatement technology. It turns out that interdependencies between production and abatement processes may make the industry increase pollution when the effluent charge rates are increased.