Monopoly Power and the Optimal Control of External Costs

Paul Burrows

University of York

Gary Yohe

Wesleyan University and Yale University

I. Introduction

The extensive literature on production externalities has paid too little attention to the importance of controlling external costs when the generators of the externality exercise monopoly power in the goods market.[1] What is more, the relatively few studies of this subject, found in the specialist environmental economics journals, appear to have reached an impasse. They have concluded that there is no single Pigouvian tax instrument that can achieve a socially optimal (efficient) level of the external cost, even if problems of information cost to the regulatory agency are ignored. In addition, the particular tax instrument that has previously been advocated will, in certain circumstances, involve the subsidization of the monopolist's efforts to reduce the external cost, while generating no revenue to finance the subsidy.[2]

This paper suggests that the source of the policy problem is that the

[1] Buchanan(1969) did consider monopolists, but he only posed the problem and was nihilistic vis-à-vis the prospects for control policies. None of the general surveys of externality theory (Mishan (1971), Ng (1979) etc.) deal with control policies outside a competitive context.

[2] This instrument, which will be referred to below as a "modified Pigouvian" tax, is described in Misiolek (1980). Barnett (1980) also generated a similar result, and states the conclusions to be drawn from the single tool approach in their most concise form: the second best charge to be imposed upon a monopoly will (1) fall below the marginal harm of its effluence and (2) is diminished as the demand for the monopolist's product becomes more inelastic. The latter conclusion is the more troublesome since the inelasticity of demand is directly related to the measure of a monopolist's market power.

[Seoul Journal of Economics, 1988, Vol. 1, No. 1]

monopolist is generating two types of external cost. Consequently optimality requires the use of *combinations* of two instruments in place of the single instruments that have been considered before.[3] The model to be used for the comparison of instruments will be outlined in section II, while in section III the exact nature of the policy problem will be explained by demonstrating the suboptimality of the traditional single instrument alternatives. In sections IV and V two possible instrument combinations are considered in terms both of their ability to generate optimal output and emissions levels, and of the information demands they make. Section VI summarizes the implications.

II. The Model

Consider a monopolist whose production possibilities in manufacturing a good X are represented by $X = F(L,E)$, where L and E respectively indicate the quantities of labor and emissions employed and $F(L, E)$ is linearly homogeneous and twice differentiable. Let both inputs display diminishing, positive marginal productivities, and assume that the monopolist always maximizes profits. Emissions are viewed as an input into the productive process and not as an undesirable joint product of that process for several reasons. First of all, there is no formal distinction between the two because the most general representation of our production function, $0=f(L, E, X)$, does not differentiate between inputs and outputs. Moreover, intuition supports the input conceptualization when property rights are assigned to those who suffer the damage costs of emissions providing "clean air" is just like providing labor. The welfare generated by the productive "use" of emissions can, therefore, be reflected simply as the derived demand schedule of the emissions input; and the ease with which a production process can be cleaned up is captured by the elasticities of substitution between emissions and the other factors of production.[4] Returning to the model, complete the flows by representing

[3] Bargains over externalities would not provide an optimal solution. See Burrows (1981), p. 378.

[4] Pollution has been modeled as an input elsewhere. The reader is referred to Yohe (1976,1979a, 1981), Burrows (1977), and Ingene and Yu (1981). The only restriction on the

the downward sloping demand schedule for X by $P(X)$, and assume that labor is available at a constant price w. Finally, let $C(E)$ and $S(E)$ represent respectively the private and external costs of emissions, and presume that both marginal costs are positive and increasing in the relevant ranges.[5]

We will compare the abilities of various control mechanisms to achieve optimality, so a careful characterization of the best production circumstance, (L^*, E^*, X^*), is essential. With the appropriate assumption concerning the constancy of the marginal utility of income (L^*, E^*, X^*) is the solution to

$$W \equiv \underset{L,\ E}{\mathrm{Max}} \int_0^{F(L,E)} P(s)ds - wL - C(E) - S(E) \qquad (1)$$

with

$$X^* = F(L^*, E^*).$$

The first order conditions that characterize (L^*, E^*) are therefore

$$P[F(L^*, E^*)]F_1(L^*,E^*) - w = 0, \text{ and} \qquad (2a)$$

$$P[F(L^*,E^*)]F_2(L^*,E^*) - C'(E^*) - S'(E^*) = 0. \qquad (2b)$$

Equations (2) will be used repeatedly as benchmarks as we turn to the available control options.

III. Single Instrument Alternatives

One frequently analyzed control would impose upon the polluting monopolist a Pigouvian emissions tax equal to the marginal external cost of emissions at the optimum level of emissions, i.e.

$$t_1^* = S'(E^*).$$[6]

specification of $F(L,E)$ to note is that the isoquants never intersect the emissions axis; output can never be produced by "employing" only emissions.

[5] The following argument is generalizable to the case in which $C(E) \equiv 0$, but even casual observation suggests that the days of costless disposal are over. In addition, the generalization allows for discussions of more stringent control than the status quo, and not necessarily "starting from scratch".

[6] See Buchanan (1969), for example.

However, to prescribe such a charge would not only fail to achieve optimality, but would also run the risk of actually *reducing* welfare. To see why, notice first of all that a profit maximizing monopolist would choose its input combination $(\bar{L}, \bar{E})$ by solving

$$\max_{L,E} \; P[F(L,E)]F(L,E) - wL - C(E) - t_1^* E.$$

The resulting first order conditions,

$$\{P[F(\bar{L},\bar{E})] - F(\bar{L},\bar{E})\,P'[F(\bar{L},\bar{E})]\}\,F_1(\bar{L},\bar{E}) - w = 0, \text{ and} \tag{3a}$$

$$\{P[F(\bar{L},\bar{E})] - F(\bar{L},\bar{E})P'[F(\bar{L},\bar{E})]\}\,F_2(\bar{L},\bar{E}) - C'(\bar{E}) - S'(E^*) = 0 \tag{3b}$$

duplicate (2) only if $p'[--]=0$. This first Pigouvian alternative can achieve optimality, therefore, only if the monopolist has no monopoly power! Secondly, note that any firm could lower its tax liabilities in response to t_1^* either by "substituting out" of emissions (i.e. switching processes) or by reducing its output. Because a monopolist starts by producing too little, the latter response can reduce welfare *even though emissions fall.*[7]

It was this observation that led some authors to suggest a "modified Pigouvian" tax that, under certain conditions, would actually subsidize monopolistic polluters.[8] The suggestion, based not on optimality but only on guaranteeing that welfare will not fall, subtracts from t_1^* a reflection of a firm's monopoly power, the difference between its price and marginal revenue at X^*. In our notation,

$$t_2^* = t_1^* - \{P(X^*) - MR(X^*)\} = t_1^* - X^* P'(X^*) \tag{4}$$

which will be negative (a subsidy) if monopoly power is strong relative to the size of the external cost. Needless to say, the thought of granting monopolistic polluters emissions subsidies in an amount positively correlated with their monopoly power, with no associated tax commitment, has raised some eyebrows.[9] But the "modified Pigouvian" tax can also be criticized on efficiency grounds. Although it can, in fact, be optimal if

[7] Burrows (1981)showed this result in the context of variable processes by using a modified form of conventional marginal abatement cost analysis

[8] Asch and Seneca (1976) and Misiolek (1980).

[9] Misiolek (1980).

$F(L,E)$ is a Leontief fixed coefficient schedule, the tax will be suboptimal if the L/E ratio is variable. The reason for this, of course, is that a Leontief technology specifies the appropriate L/E ratio so that only output needs adjustment.[10]

A comparison of the two Pigouvian tax alternatives can be accomplished in the more general case of flexible input ratios with the use of some geometry. The optimal production point, Z^* in Figure 1, shows (L^*,E^*) being used to produce X^*. Isowelfare loci that reflect the utility of X and the disutility of L and E are elipses around Z^*; the further from Z^*, the lower the welfare.[11] Locus *PEP* represents the price expansion path as the cost of emissions change, and point C along that path is designated the no tax point; the isoquant through C has some slope to it, though, because there are some private costs of emissions.[12] For the homothetic production relationship depicted in Figure 1, a point such as D along say OZ^* to the left of C, must be the standard Pigouvian tax solution to $t^*_1 = S'(E^*)$; for the case drawn, therefore, the standard tax would unambiguously lower welfare.[13] By way of contrast, welfare would be improved by the "modified Pigouvian" instrument, a subsidy in this case, which would move the production point toward the welfare maximizing position along the given *PEP*, to a point like E. Notice once again that even the

[10] The suboptimality of the "modified Pigouvian" tax can be shown using conventional marginal external cost/marginal abatement cost geometry. The advantage of the new formulation presented here is that it can be used to contrast the impacts of single-tax instruments and instrument combinations.

[11] Totally differentiating (1) along an isowelfare locus, we find that

$$\frac{dL}{dE}\bigg/_{W=W} = \frac{\{P[F(L,E)]F_E\,(L,E) - C'(E) - S'(E)\}}{\{P[F(L,E)]F_L(L,E) - w\}}$$

Starting at point a in Figure 1 and moving to the right on the lower negatively sloped arc, E increases driving F_E down $P\,[-]$ down but C' and S' up. The numerator must then change sign causing $\frac{dL}{dE}$ to change sign and turning the locus upward. With L then increasing through b, sign of the denominator must eventually change, too. $\frac{dL}{dE}$ must therefore turn negative and point the locus toward the northeast and point C. With L increasing, E decreasing and finally X decreasing, though, the numerator must again turn positive so that the locus points downward through d to complete the arc.

[12] If we were starting from costless disposal C would lie on a ridge line.

[13] It should be noted that homotheticity is not required for this result; it merely simplifies the geometry.

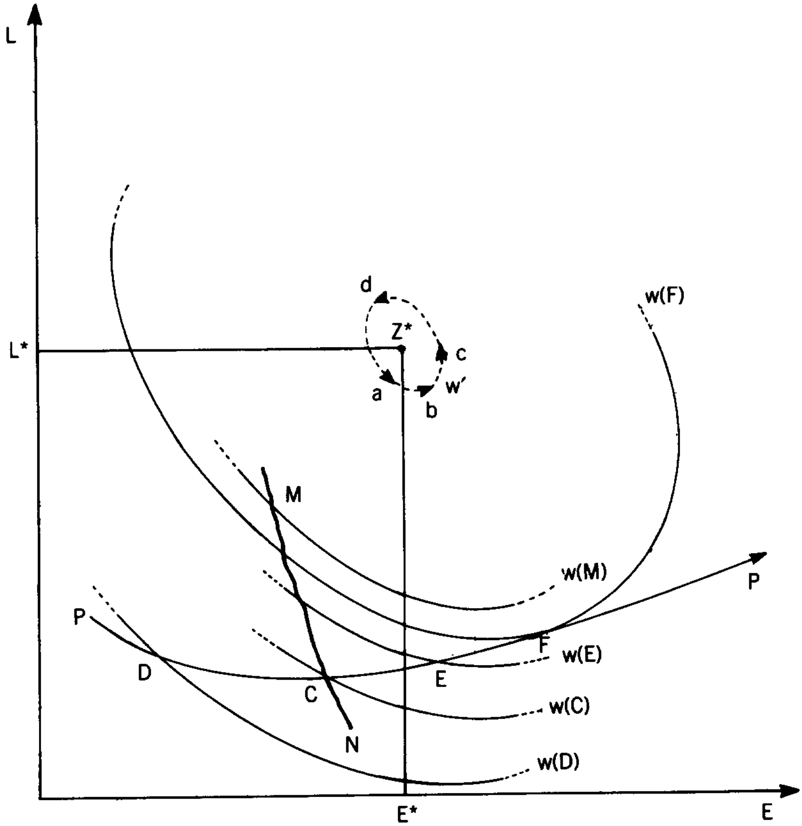

FIGURE 1.

Note by construction that $w' > w(M) > w(F) > w(E) > w(C) > w(D)$. The welfare comparisons drawn in the text depend upon these relationships.

single tax optimum, point F, can never coincide with Z^* unless the *PEP* is linear through C and Z^*; i.e., unless $F(L,E)$ displays fixed Leontief coefficients. Fixed production coefficients are, in fact, necessary and sufficient conditions for a single tax to be capable of eliciting the optimum.

To complete the criticism of the single tax proposals, consider now Figure 2. It shows the possibility that easy substitution out of emissions might cause the *PEP* to bend back on itself. Output reductions would be minimal, therefore, if the cost of emissions were to rise, and an emissions tax would always improve welfare (up to a point). It is important to notice

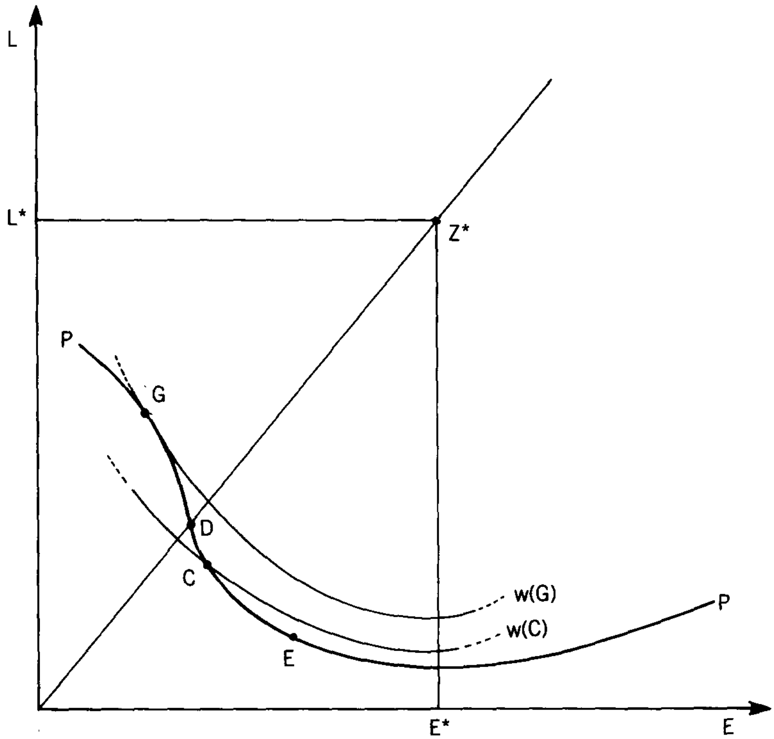

FIGURE 2.
Note that $w(G)$ represents maximum welfare subject to the price expansion path PEP; $w(G) > w(C)$.

that the conventional emissions tax t_1^* would actually be *too small* to maximize welfare (point G maximizes welfare, not point D). Even so there is a distinct possibility that, in this case, t_1^* would dominate the "modified Pigouvian" instrument t_2^* (a subsidy here), since point D may be preferred to points on PEP to the right of C. From these comparisons of the single Pigouvian tax remedies the need for some other form of control policy is unmistakable.

IV. Emissions Taxes with Output Subsidies

The fundamental difficulty with the traditional Pigouvian alternatives is that they attempt to solve the problem of *two* externality sources with one instrument. The two external costs are the loss of consumer surplus imposed on consumers by the exercise of monopoly power, and the damage suffered by the victims of the production externality; and these give rise to two policy objectives, socially optimal output and emissions.[14] Coupling an emissions tax with an output subsidy financed, at least in part, by the tax revenues, could overcome this difficulty by specifying an assignment of instruments to objectives. Setting aside administrative considerations for the moment, we can show that this dual policy can even achieve the optimal production point (L^*, E^*, X^*). Algebraically, the demonstration rests upon monopolist's problem of maximizing

$$(1 + \tau_3)p(X)X - wL - C(E) - t_3E$$

when confronted with an emissions tax t_3 and an output subsidy τ_3. The relevant first order conditions given $X = F(L,E)$,

$$(1 + \tau_3)\ \{P[F(\hat{L},\hat{E})] - F(\hat{L},\hat{E})P'[F(\hat{L},\hat{E})]\}\ F_1(\hat{L},\hat{E}) - w = 0 \text{ and}$$

$$(1 + \tau_3)\{P[F(\hat{L},\hat{E})] - F(\hat{L},\hat{E})P'[F(\hat{L},\hat{E})]\}\ F_2(\hat{L},\hat{E}) - C'(\hat{E}) - t_3 = 0.$$

reduce to (2a) and (2b) if

$$t_3^* = S'(E^*) = t_1^*, \text{ and} \tag{5a}$$

$$\tau_3^* = -X^*P'(X^*)\ [P(X^*) - X^*P'(X^*)] > 0 \tag{5b}$$

As a result, specifying t_3^* and τ_3^* as in (5) would guarantee that the profit maximizing monopolist would employ $\hat{E} = E^*$ and $\hat{L} = L^*$ to produce $\hat{X} = X^*$. Geometrically, the two tools operate along the radial coordinates spanning of the positive quadrant of input space in the following way: t_3 moves the firm along any isoquant while τ_3 moves the firm along any output expansion path. The quadrant is thus covered, and it should be no surprise that the two instruments can be designed to achieve Z^*. Equations (5) simply show us how.

This result can be explained in terms of marginal abatement cost/marginal external cost analysis. In essence, the output subsidy τ_3^* is

[14] Breaking-even would represent a third policy objective for which a third policy tool would be required. A tax/subsidy on labor would do the trick, but it is ruled out here on the grounds of practicability.

designed to set marginal revenue plus subsidy equal to marginal private cost. The producer is thereby induced to take account of the full social cost (including the net cost to consumers) of abatement through a cut in output. The emissions tax is set equal to the level of external cost at the level of pollution for which the marginal cost of the least cost method of abatement is equal to marginal external cost.

But what about the administrative considerations that we have buried? As far as computation is concerned, the emissions charge t_3^* would simply equal the Pigouvian charge that a perfectly competitive polluter would face. The output subsidy would be more difficult to specify properly, though, and there is no guarantee that the program would break even. Still, the beauty of the pairing of instrument with objective, vividly portrayed by the geometry, is reassuring. Moreover, computing both requires no more information than was presumed by τ_2^*; i.e., as in the modified Pigouvian scheme, the regulator needs to have some measure of the monopolists' market power, marginal revenue as compared to price, and the social cost of emissions.

If the combination $(t_3^* \quad \tau_3^*)$ were not to breakeven, of course, the political problem of subsidizing monopolists would reappear, but to a lesser degree. As shown in Figure 1, however, constraining the system to breaking even along the locus MN can lower welfare from the maximum and destroy the simplicity of setting $t_3^*=S'(E^*)$. But since the breakeven locus MN lies everywhere above the PEP to the left of the no tax solution at point C, welfare would necessarily improve if $t_3^*=S'(E^*)$ were used to finance as much of an output subsidy as breaking even would allow. More specifically, welfare at M necessarily exceeds welfare at C.[15]

V. Optimality Without an Output Subsidy

Suppose now, for the sake of argument, that output subsidies of any kind would be ruled out for political reasons, even if financed wholly or in

[15] Notice that along MN to the left of C, output rises in response to subsidy and emissions fall in response to taxation. Welfare must, therefore, rise, so MN must lie above $W(C)$ to the left of C.

part by the emissions tax. The optimal point could *still* be achieved by a process switching subsidy that rewarded polluters for their efforts in increasing their output/emissions ratio, but only with a significant increase in administrative difficulty. To see why, let $\Gamma(X/E)$ represent a process-switching subsidy schedule with $\Gamma\ (X/E) > 0$. The monopolist, facing $\Gamma(X/E)$ and an emissions charge t_4 would then maximize

$$P(X)C - wL - C(E) - t_4E + \Gamma(X/E).$$

The relevant first order conditions can be shown to reduce again to (2) if

$$t_4^* = S'(E^*) + (X^*)^2P\ (X^*)/E^* \tag{6a}$$

and $\Gamma(X/E)/E$ solves the differential equation

$$\Gamma(X/E)/E = XP'(X) \tag{6b}$$

at $(L^*,\ E^*,\ X^*)$.[16] This instrument combination introduces two incentives for a firm. The right hand term in the emissions tax expression (6a) encourages the firm to take account of the net impact on consumers of a cut in output when choosing its level of emissions, and the choice is E^*. The amount of subsidy (6b) paid at the optimal process choice and emissions level, X^*/E^* and E^*, shifts the firm's marginal cost schedule down to intersect the marginal revenue schedule $X^*P'(X^*)$ units of currency below the demand schedule at $\hat{X} = X^*$, thereby inducing the choice of the optimal level of output, X^*.

[16] Precisely the same expressions for t^*_4 and $\Gamma'(-)$ would emerge if $\Gamma(-)$ were defined in terms of an alternative process indicator, the L/E ratio. The monopolist's first order conditions require that $(\bar{L},\bar{E})$ satisfy

$$[P(\bar{X}) - \bar{X}P'(\bar{X})]F_L\ (\bar{L},\bar{E}) - w + \{\Gamma'(\bar{X}/\bar{E})F_L(\bar{L},\bar{E})/\bar{E}\} = 0 \text{ and}$$
$$[P(\bar{X}) - \bar{X}P'(\bar{X})]F_E\ (\bar{L},\bar{E}) - C'(\bar{E}) - t_4 + \Gamma'(\bar{X}/\bar{E})[(\bar{E}\ F_E(\bar{L},\bar{E}) - \bar{X}]/\bar{E}^2 = 0.$$

where $\bar{X} = F(\bar{L},\bar{E})$. Setting $\Gamma(X/E)$ to solve

$$\{\Gamma'(X/E)/E\} = XP'(X)$$

along with

$$t_4^* = S'(E^*) - X^*P'(X^*)\ F_E\ (L^*,E^*) + X^*p'(x^*)[F_E(L^*,E^*) - \frac{X^*}{E^*}]$$
$$= S'(E^*) + (X^*)^2\ P'(X^*)/E^*$$

will cause these conditions to reduce to (2) at (L^*,E^*,X^*). Thus $(\bar{L},\bar{E},\bar{X}) = (L^*, E^*, X^*)$

Aside from the computational problems involved in solving (6b), the administrative ease of having a single *emissions tax* for all firms is destroyed by (6a) unless $P'(X') = 0$(the firm has no market power). Both output and process-switching subsidies are firm specific, of course, but the notion of setting one effluent charge for all emitters of a given pollutant, be they competitors or monopolists in their product markets, is surely attractive.

VI. Conclusions

This paper has attempted to come to grips with the failure of single tax instruments to optimally control external costs generated by monopolistic production. The implications of the analysis are:

(1) an emissions tax with an output subsidy can achieve optimal levels of output and emissions. The fact that the subsidy would be financed, in part at least, by the tax might moderate the "political" objections that have been thought serious for single-instrument output subsidy proposals;

(2) an emissions tax with a process-switching subsidy can also achieve optimal output and emissions, without the controversial output subsidy. However, the computational complexity of this combinations, in particular the firm-specific emissions tax, argues in favor of exploring further the political feasibility of an output subsidy financed by an emissions tax. Explaining the possibility of simplified approximations to the optimal combination of firm-specific emissions tax and process subsidy might also pay dividends.

References

Asch, P., and J. J. Seneca. "Monopoly and External Cost: An Application of Second Best Theory to the Automobile Industry ", *Journal of Environmental Economics and Management,* 3, 1976, 69-79.

Barnett, A. H. "The Pigouvian Tax Rule under Monopoly." *American Economic Review,* 70, 1980, 1037-41.

Buchanan, J. M. "External Diseconomies, Corrective Taxes and Market Structure", *American Economic Review,* 59, No. 1, March 1969, 174-7.

Burrows, P. "Pollution Control with Variable Production Processes", *Journal of Public Econo-*

mics, 8, 1977, 357-67.

Burrows, P. "Controlling the Monopolistic Polluter: Nihilism or Eclecticism?", *Journal of Environmental Economics and Management,* 8, 1981, 372-80.

Ingene and Yu. "The Backward Incidence of Pollution Control in a Rigid Wage Economy", *Journal of Envirnomental Economics and Management,* forthcoming.

Mishan, E. J. "The Post-war Literature on Externalities; An Interpretative Essay", *Journal of Economic Literature,* 9, March 1971, 1-28.

Misiolek, W. S. "Effluent Taxation in Monopoly Markets", *Journal of Environmental Economics and Management,* 7, 1980, 103-7.

Ng, Y. K. *Welfare Economics,* Macmillan, London, 1979.

Yohe, G. W. "Substitution and the Control of Pollution: A Comparison of Effluent Charges and Quantity Standards under Uncertainty", *Journal of Environmental Economics and Management,* 3, 1976, 312-24.

__________. "The Backward Incidence of Pollution Control: Some Comparative Statics in General Equilibrium", *Journal of Environmental Economics and Management,* 6, 1979a, 187-98.

__________. "Should Sliding Controls Be the Next Generation of Pollution Controls?", *Journal of Public Economics.* 15. 1981. 251-67.