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Public Investment Criteria for Water Oriented Recreation in the Lake Erie Basin

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INTRODUCTION

Research results fall under two headings, dealing with: (1) economic criteria and (2) recreation data. The greatest time commitment and effort was made in the former area, and a journal article on economic criteria was published. This article will serve as the principal part of the present report. Activities are described below under each of the headings:

ECONOMIC CRITERIA

The principal research result of the present project takes the form of a journal article, "Pricing Pollution and Other Negative Externalities" , Bell Journal of Economics and Management Science, Vol. 3 (Spring, 1972), pp. 252-266. A reprint is enclosed.

Prior to the publication of the reference article, a number of basic flaws existed in the relevant economic theory. These included:

(1) An implicit assumption of fixed proportions between conventional product and pollution outputs.

(2) A mistaken symmetry in compensation and bribery as means of internalization.

(3) A confusion between internalization and rationing.

(4) Misconceptions on the possibilities of blackmail in pollution control.

The author worked through a consistent line of analysis to correct all the above flaws, the second of which was embodied in received theory in the forms of the Coase Theorem. The Coase

Theorem states that ownership of a polluting factor can be assigned to either the pollution originator or the pollution receiver without affecting the allocation of resources. This Theorem is, in general, false, as the author has now shown. At least two kinds of errors were made by the proponents of the Coase Theorem. The first was to begin with property rights to an assumed polluting factor, rather than to the pollution output itself. The second was to consider marginal profits only, to the exclusion of total profits. Certain critics of the Coase Theorem has previously made the error of considering total profits only, to the exclusion of marginal profits. In the present article of reference, the author showed that the two profit concepts can be reconciled only in the case of internalization by compensation, not with internalization by bribery.

A sequel to the above article will appear in the Bell Journal of Economics and Management Science, Vol. 4 (Spring, 1973). This second piece will further elaborate the necessary conditions for proper assignment of property rights.

RECREATION MEASUREMENT

Important Variables

Application of economic criteria to a comprehensive measure of demand for water-oriented recreation must relate to quantity of recreation consumed, measured as either activity days or visits, to the prices paid, measured as travel expenses to the recreation site plus admission fees. At least three effects must be reflected in shift parameters: long term changes in income levels, natural site quality, especially water quality, and congestion. Particular kinds of recreation, such as boating or camping, require additional expenditures by recreationists for equipment and the damand prices of these kinds of recreation must be reckonned higher as a result. To the extent that strict complementarity exixts among the goods consumed, such as travel to the site and admission, demand is for the combined total of complementary goods. This means that changing the policy variable, admission fees, will have predictible effects on distance travelled and hence on attendance.

The Simplest Case: No Shift Parameters

The empirical approach implied by the above summary of the problem is easiest to frame when the shift parameters are not important. Thus, a reference case may be conceived in which a series of water-based recreation sites are available at different ditances from a series of population centers. If all of the recreation sites are large enough that there is no crowding (no congestion effects) and site natural qualities the same everywhere, then there is no reason to expect recreationists to go to any site other than the nearest one. They have no incentive to spend time and money going further. Since the sites are at different distances from the population centers, travel costs are different and so is attendance, as a fraction of the population served. In this simple case, none of the three shift parameters are important and a demand curve can be constructed from a simple regression of population participation against distance from site, with each combination of population center and recreation site taken as one observation. The dependent variable is the participation rate and the independent variable is the distance travelled. Distance travelled is converted to dollars per user-day using established travel time relationships. Observations could be made for the season as a whole or for selected days, but would have to be made at the same time period for all sites.

The shift parameter due to changes in recreationists' income would be reduced to unimportance by taking the observations within a short period of time, e.g. a recreation season, or a year, over the course of which no important income change is expected to take place. The other two shift parameters, quality and crowding, were eliminated by the special considerations introduced in constructing the model.

Incorporation of Shift Parameters

In a practical situation, there is no possibility that the shift parameters can be held fixed. A general formulation is then the one used in the present analysis: Participation rates (of population centers) in each of the recreation classifications at a given site are set up as functions of

(1) Distance travelled by recreationalists to the site. The most comprehensive formulation would take account of the distance travelled by each individual. Since this variable is being used in a linear regression model, however, the implicit assumption of linearity over the relevant range makes equally valid the use of the weighted average distance travelled at each site and for particular days or time periods.

(2) Total recreation use (in whatever recreation category) at all sites. This variable gives a measure of the extent of crowding. On major holidays during the summer, one would expect the total recreation use to be greatest. It would be less on interveining weekends, still less during the week and, of course, drop near zero

at off-season times.

(3) Proximity to population. This variable normalizes crowding effects in that it is expressed as the ratio of population to distance, distance being measured from the center of the population to the recreation site, with finite limits on distances considered according to type of use. For example, the limit on day use is set at 200 miles.

(4) Natural site quality. This variable refers to natural attributes of the site, as distinguished from those created by crowding or an absence of crowding. No attempt is made to measure it directly, though values can be imputed through the use of dummy variables. Thus, in a regression across all sites, observations applicable to any one site are given a separate variable which does not exist for any other site. The regression coefficient of this variable gives an index of quality

Regression analysis. Variable (1) sets up the demand relationship and should have a negative coefficient. Variables (2) and (3) in combination deal with the crowding phenomenon. The coefficient of variable (2) should be positive, but variable (2) is hypothesized to have a greater effect on attendance at sites distant from population centers than at those close by. Recreation sites close to population centers will experience the effects of crowding sooner than will more distant locations. For this reason, it is necessary to introduce variable (3), which increases in proportion to effective proximity of population. The effect of variable (3) will be greatest for close-in recreation sites and should have a negative coefficient that will serve as a correction on the effects of variable (2). It is important to note that both variables (2) and (3) will introduce scale effects. Variable (2) will be larger the greater the supply of recreation facilities; variable (3) will be greater the greater the number of potential users of recreation facilities. Hence, the above model should be adaptable to various geographic areas beyond the Lake Erie Basin.

Variable (4) takes account of the shift effects of natural site quality. The coefficient of (4) may be either positive or negative. Its relative significance is all that matters for the present model. No shift variable for income level is necessary if observations are made within the same year, but would be required with observations extending over several years time.

It will be noted that daily observations are necessary for the application of the above model. Differences in crowding cannot be detected using variable (2) unless differences in total recreation use for all sites can be observed. This means, in particular, that annual visitation averages or totals are not useful for the analysis, nor is it possible to substitute year-by-year attendance data. Income effects become important over longer periods of time, as do changes in site quality. Year-by-year comparisons should be made to distinguish income and quality effects, particularly to identify effects arising from pollution. But such year-by-year analyses cannot be conducted unless crowding effects are properly identified through within-year analysis, as previously described.

Recreation data

Recreation data meeting the needs of the above model were collected, at least for selected days, in Ohio in 1958 and 1963 and in Michigan 1963. After extensive investigations in both states, however, it was found impossible to obtain these data. In Ohio, the original figures had been discarded and averages published. In Michigan, some of the original data were found on IBM cards but it proved impossible to get all that were collected or to get the information off the cards that existed. As in the case of Ohio, the only data available took the form of aggregates in published reports. Thus, the result of these investigations was to establish that the empirical base for analysis of the preceding variables was not available.

CONCLUSION

A reconstruction of economic criteria for evaluating the quality effects of pollution was completed and published. An econometric framework was developed and an investigation made of data sources for evaluating recreation variables. The theoretical construction constitutes the principal contribution of the research project. The econometric model awaits testing when adequate data becomes available.

APPENDIX

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Pricing pollution and other negative externalities

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Pricing pollution and other negative externalities

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Equilibrium conditions are described for pollution or "externalities of production" treated as substitute products. The results are contrasted with those based on traditionally assumed fixed proportions between product and waste outputs. The "neutrality of bribery or compensation" argument is refuted. With linear homogeneous production functions, compensation leads to exhaustion of product; bribery does not. Only certain selected production functions and conditions can lead to positive aggregate profits in a bribe-paying industry. Requirements are described. The analysis is applied to a number of related issues: the blackmail problem, third party pricing, and public goods aspects.

1. Introduction

■ Discommodities are generally externalities. The incentive is to disown rather than to own, to avoid rather than to ration. But avoiding and disowning are becoming more difficult as population and GNP grow. So it is that economic theory faces a problem of increasing magnitude: the allocation of negative externalities.

Intuitively, one would expect all of the familiar rules of market operation to apply to discommodities, except in reverse. Supply should be negatively sloped. Demand should be positively sloped. And the originator of a discommodity should pay the receiver to take it off his hands. But economic theory is not so constructed at the moment. An imposing part of received theory on the economics of pollution asserts that legal responsibility can be assigned to either the pollution originators or to those damaged without affecting the allocation of resources. Either way, it is held, the parties could negotiate a monetary settlement that would lead to identical waste output in the absence of transactions costs.

The argument originated with R. H. Coase and has been developed in a series of supporting and qualifying articles.[1] It has recently appeared in what is perhaps the leading scholarly monograph

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[1] See Coase [5]; and Buchanan and Stubblebine [4], Davis and Whinston [7], and Wellisz [15].

on the economics of pollution.[2] As noted above, neutrality is claimed only in the absence of transactions costs. This disclaimer limits consideration to private goods, and the argument will be evaluated in that context, though a final part of the present article will extend the theory developed here into public goods. A second limitation, as often implicit as explicit, is that indirect effects of the distribution of income on demand are ignored.[3] In this sense, the analysis is conducted in a partial equilibrium context. Finally, we shall be concerned with only unilateral, as opposed to multilateral, externalities.[4]

Others[5] have pointed to certain anomalies in the Coase argument, though their criticisms imply an alternative kind of symmetry, i.e., that compensation and bribery are equally workable market alternatives. The objection they make is to that part of the thesis that predicts the same allocation of resources with either payment alternative.

The main conclusion of the present paper is that the transaction for internalizing a negative externality cannot, in general, run either way. We shall attempt to show that viable market operation requires that an internalizing payment must in general take the form of compensation running from the discommodity originator to the damaged party. A transaction in the opposite direction, known as bribery, cannot exist except in rare cases dependent on fortuitous circumstances. Section 2 presents an equilibrium formulation with the externality treated as a substitute product. Section 3 summarizes and restates in a more general way the argument for neutrality of compensation and bribery, or the "Coase Theorem," as we shall call it. Section 4 gives the analytical basis for the author's conclusion that bribery and compensation are far from symmetrical. Section 5 deals with a number of related issues, largely theoretical and largely raised by discussions in the literature on the Coase Theorem.

The theoretical analysis and the conclusions of the present work appear in the context of pollution control. Nevertheless, it is hoped that the analysis of bribery may be suggestive for such diverse topics as the economics of crime and the logic of the agricultural soil bank program. The reference is to the special circumstances that surround a situation where payment is made for not doing something, as described in the present analysis of bribery.

2. Economics of internalization

■ A standard treatment of multiproduct commodity pricing provides the basis for the theory of internalization. For positive externalities, the results are the same as in conventional commodities markets, though the externalities literature has not been so developed. For negative externalities, the results are unfamiliar.

A general-purpose statement of the optimization problem can be made with externality J, either a commodity or a discommodity, to be internalized. The originator, A, of J sees the classical production

[2] See Kneese and Bower [11], pp. 98–109.

[3] The effects of compensation and bribery are, of course, not neutral when the distribution of income affects output decisions. For a discussion of this case, see Dolbear [8].

[4] For discussion of some of the problems involved with multilateral externalities, see Davis and Whinston [6].

[5] See Boyd [2], Bramhall and Mills [3], and Wellisz [15].

problem as

$$\text{Maximize} \quad \pi_A = P_A X_A \pm P_J X_J - wL_A - rC_A \tag{1}$$

$$\text{Subject to} \quad X_A - F(X_J, L_A, C_A) = 0 . \tag{2}$$

The receiver, B, of J sees it as

$$\text{Maximize} \quad \pi_B = P_B X_B \mp P_J X_J - wL_B - rC_B \tag{3}$$

$$\text{Subject to} \quad X_B - G(X_J, L_B, C_B) = 0 . \tag{4}$$

Conventional products A and B are produced in quantities X_A and X_B and sold for prices P_A and P_B. There are two inputs, labor, L, and capital, C, priced at wage rate w and interest rate r. A quantity X_J of the externality J is produced by A and received by B. The internalization price is P_J. The sign convention before the J variable is to be interpreted symmetrically. Thus, if J is a positive externality, the plus sign in (1) and the minus sign in (3) apply. If J is a negative externality, the signs are reversed. We assume that prices are viewed parametrically by all parties and constant returns to scale obtain throughout. Second-order conditions are those required for quasi-concavity.

Internalization takes place through the establishment of markets that produce a positive price P_J in place of the pre-internalization price $P_J = 0$. J. E. Meade's celebrated example of externality, the production of honey from nectar in apple blossoms, provides an example of a positive externality.[6] Interpret commodity A as apples, commodity B as honey, and externality J as nectar; $J \equiv N$, with the plus sign before the second term on the right hand side of (1) and a minus in the same position in (3). Internalization then produces the familiar results

$$P_N = -P_A \frac{\partial X_A}{\partial X_N} \tag{6}$$

$$P_N = P_B \frac{\partial X_B}{\partial X_N} . \tag{7}$$

One conspicuous difference is that Meade designed his analysis to deal with indirect as well as direct effects. The latter are the only effects of interest here. More important from the standpoint of externalities, however, is the way in which the commodity nectar is treated. Meade introduced no such commodity explicitly. Using our notation, he employed the following production functions in place of our (2) and (4):

$$X_A - H_A(L_A, C_A) = 0 \tag{8}$$

$$X_B - H_B(X_A, L_B, C_B) = 0 . \tag{9}$$

In effect, (8) and (9) require that apples and nectar be produced as strictly joint products, i.e., $X_N = kX_A$ and $\frac{\partial X_N}{\partial X_A} = k$.[7] The present

[6] See [13].

[7] Meade finds a tax needed on honey production in the amount (using our notation) of:

$$\text{Tax} = \frac{\partial X_B}{\partial X_A} \cdot \frac{X_A}{X_B} X_B P_B = \frac{\partial X_B}{\partial X_A} X_A P_B .$$

In our formulation, the tax is

formulation, of course, allows the conventional commodities and the externality to be viewed as substitute products.

Now, reverse the externality and consider the case of pollution. Interpret J as P and use the minus sign before P_P in (1) and the plus sign before P_P in (3). These sign changes now state that the polluter, industry A, must pay a price equal to P_P for each unit of pollution produced. The price (effluent tax) is paid to industry B for damages. We can imagine that industry A is located upstream of industry B. The former produces commodity A and pollution P. The latter produces commodity B and involuntarily receives pollution in the course of using river water. Pollution has a negative effect on the production of commodity B. The first-order conditions of maximization are the same as before except for the following new internalization price conditions:

$$P_P = P_A \frac{\partial X_A}{\partial X_P} \tag{10}$$

$$P_P = -\,P_B \frac{\partial X_B}{\partial X_P}. \tag{11}$$

Compare equations (6) and (7). Since prices are everywhere positive, the marginal production conditions must be of opposite sign in (10) and (11) from what they were in (6) and (7). Our intuition is further confirmed by analyzing supply and demand conditions in the neighborhood of equilibrium. See the summary of production and market conditions in Tables 1 and 2.[8]

$$P_N X_N = X_N P_B \frac{\partial X_B}{\partial X_N}.$$

The two formulations are equivalent if

$$\frac{X_N}{X_A} = \frac{\partial X_N}{\partial X_A}$$

and this will be the case when

$$\frac{X_N}{X_A} = \frac{\partial X_N}{\partial X_A} = k.$$

[8] The first-order conditions for maximization of equation (1) subject to (2) derived using a Lagrangean multiplier λ are:

$$-w + \lambda \frac{\partial F}{\partial L_A} = 0 \tag{i}$$

$$-r + \lambda \frac{\partial F}{\partial C_A} = 0 \tag{ii}$$

$$\pm P_J + \lambda \frac{\partial F}{\partial X_J} = 0 \tag{iii}$$

$$P_A - \lambda = 0 \tag{iv}$$

$$X_A - F(X_J, L_A, C_A) = 0. \tag{v}$$

The effect of a small change in P_N is found by solution of the following system (where superscripts designate partial differentiation), based on equations (i)

These results were, of course, all implicit in the statement of the internalization problem in equations (1) through (4), but this statement was not arbitrary. The results conform to the underlying utility relationships one would use to define commodities (positive externalities) and discommodities (negative externalities). Thus, in output A-output J space, there are indifference curves with slope

$$\left(\frac{\partial X_A}{\partial X_J}\right)_{U_0} = -\frac{(\partial U/\partial X_J)}{(\partial U/\partial X_A)}. \tag{12}$$

Since A is a conventional commodity, $\frac{\partial U}{\partial X_A} > 0$. When $J \equiv N$, $\frac{\partial U}{\partial X_J} > 0$. When $J \equiv P$, $\frac{\partial U}{\partial X_J} < 0$. Compare the production conditions for industry A in Table 1. Analogous relationships can be defined in output B-input J space.[9]

Internalization of the negative externality was conducted above by the process of compensation. Bribery internalizes by making the

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through (v):

$$\begin{bmatrix} F^{L_AL_A} & F^{L_AC_A} & F^{L_AX_N} & 0 & F^{L_A} \\ F^{C_AL_A} & F^{C_AC_A} & F^{C_AX_N} & 0 & F^{C_A} \\ F^{X_NL_A} & F^{X_NC_A} & F^{X_NX_N} & 0 & F^{X_N} \\ 0 & 0 & 0 & 0 & -1 \\ F^{L_A} & F^{C_A} & F^{X_N} & -1 & 0 \end{bmatrix} \begin{bmatrix} \frac{\partial L_A}{\partial P_N} \\ \frac{\partial C_A}{\partial P_N} \\ \frac{\partial X_N}{\partial P_N} \\ \frac{\partial X_A}{\partial P_N} \\ \frac{\partial \lambda}{\partial P_N} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -1 \\ 0 \\ 0 \end{bmatrix}.$$

Let $|D|$ denote the determinant formed from the matrix of coefficients. Then, $\frac{\partial X_N}{\partial P_N} = \frac{-|D_{33}|}{|D|}$. Quasi-concavity implies that the signs of unbordered Hessians follow the rule $(-1)^s$, where s is the number of columns or rows. See Kuenne [12], pp. 181–82. The above matrix expanded by cofactors gives the third-order principal minor preceded by a negative sign: $|D| = -|D_{44,55}|$, which is an unbordered Hessian following the same sign convention. Therefore $|D| > 0$. The same sort of expansion gives $|D_{33}| = -1|D_{33,44,55}| < 0$. Hence $\frac{\partial X_N}{\partial P_N} > 0$. This is, of course, the slope of a supply curve for a conventional commodity in the neighborhood of equilibrium. By the use of symmetry, other results can be quickly derived from the same mathematical framework. Thus, with $J \equiv P$, the negative sign applies in (iii) and the (-1) is replaced by a $(+1)$ in the solutions vector, thus giving the slope of the pollution supply curve $\frac{\partial X_P}{\partial P_P} < 0$. Industry B can be handled in the same way. Replace F with G and A with B, then proceed as before. The sign convention in (iii) is reversed to give slopes of the demand curves $\frac{\partial X_N}{\partial P_N} < 0$ and $\frac{\partial X_P}{\partial P_P} > 0$ in industry B.

[9] With X_J as an input, it is necessary to solve (12) for X_J's marginal utility:

$$\frac{\partial U}{\partial X_J} = -\frac{\partial U}{\partial X_A}\left(\frac{\partial X_A}{\partial X_J}\right)_{U_0}. \tag{i}$$

Substitute (i) in a relationship analogous to (12) to obtain:

$$\left(\frac{\partial X_B}{\partial X_J}\right)_{U_0} = -\frac{\partial U/\partial X_J}{\partial U/\partial X_B} = \frac{\partial U/\partial X_A}{\partial U/\partial X_B}\left(\frac{\partial X_A}{\partial X_J}\right)_{U_0}. \tag{ii}$$

TABLE 1

OPTIMIZATION CONDITIONS

COMMODITY	INDUSTRY			
	A		B	
NECTAR	$\frac{\partial X_A}{\partial X_N} < 0$	SUBSTITUTE PRODUCTS P_N PRECEDED BY +	$\frac{\partial X_B}{\partial X_N} > 0$	INPUT AND OUTPUT INCREASE TOGETHER, P_N PRECEDED BY −
POLLUTION	$\frac{\partial X_A}{\partial X_P} > 0$	JOINT PRODUCTS P_P PRECEDED BY −	$\frac{\partial X_B}{\partial X_P} < 0$	INPUT AND OUTPUT ARE SUBSTITUTES P_P PRECEDED BY +

negative of the negative externality a commodity that is internalized in the same way as a positive externality. The problems which this creates will be explored by reference to the mechanism envisaged by Coase and others.

3. The Coase Theorem

■ The following presentation draws on a graphical exposition by Turvey, later adopted by Kneese and Bower.[10] The last two authors qualify their acceptance of the theorem in a long-run context, as we shall note, but not for the short run.

As in Section 2, above, two industries, *A* and *B*, are assumed to be producing conventional outputs *A* and *B* as well as (in the case of *A*) producing pollution and (in the case of *B*) being constrained by *A*'s

TABLE 2

INTERNALIZATION MARKETS

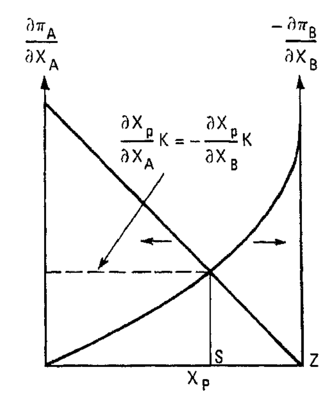
COMMODITY	INDUSTRY	
	A (SUPPLY)	B (DEMAND)
NECTAR	$\frac{\partial X_N}{\partial P_N} > 0$	$\frac{\partial X_N}{\partial P_N} < 0$
POLLUTION	$\frac{\partial X_P}{\partial P_P} < 0$	$\frac{\partial X_P}{\partial P_P} > 0$

production of pollution. Coase discusses the process in the context of bilateral monopoly, whereas our parametric treatment of prices is most consistent with universal pure competition. The situation with bilateral monopoly will be noted at a later point.

Consider Figure 1. The negatively sloped line is a supply curve for pollution expressed indirectly through marginal profits on output *A*. Outputs *A* and *P* are simultaneously expanding. If the expansion takes place with strict jointness in the production of *A* and *P*, there is a unique downward-sloping supply curve of pollution. If the output takes place with variable proportions of *A* and *P*, then the pollution supply curve depends on both prices P_A and P_B. See Tables 1 and 2.

FIGURE 1

COMPENSATION EQUILIBRIUM



[10] See Turvey [14] and Kneese and Bower [11], p. 100.

We shall allow X_A and X_P to vary independently but assume that the single downward-sloping curve in Figure 1 represents prices consistent with the processes to be described—in particular, with a compensation equilibrium at point S. $P_P = 0$ at point Z by construction. Thus, industry A is in equilibrium at Z without internalization.

The upward-sloping line indicates increasing marginal losses to B as output P is expanded and, by hypothesis, received by B. This is a demand curve for pollution with a compensation regime. See Tables 1 and 2. Variable proportions of input P and output B are possible; therefore, it is necessary to assume prices P_P and P_B such that the compensation equilibrium is reached at point S and there is no internalization of pollution at point Z. Industry B is assumed, for the time being, to have no transferable resources.

The units on the two vertical axes are adjusted so that equal vertical distances give equal dollar quantities. The production conditions of Section 2 are carried over so that both industries A and B have linear homogeneous production functions. At the compensation equilibrium, $X_P = S$ and we shall let $P_P = K$. Then by virtue of linear homogeneity, there is complete exhaustion of product:

$$\pi_A = P_A X_A - KS - wL_A - rC_A = 0 \tag{1a}$$

$$\pi_B = P_B X_B + KS - wL_B - rC_B = 0 . \tag{3a}$$

The bribery mechanism can be best understood with a supply and demand interpretation. To the right of $X_P = S$, industry B will minimize losses by paying A a bribe not to pollute. The bribe will give A more income than would the production of commodity A for sale in the market (with simultaneous production of P). To the left of $X_P = S$, industry B's losses are not as great as the size of the bribe that would be required to induce A to withhold production. Hence, equilibrium results again at $X_P = S$. Note that B's curve is now a demand for abatement, downward sloping from right to left, and A's curve is a supply of abatement, upward sloping from right to left.

The essential assumption in the argument is that pollution abatement can be treated as a commodity to be internalized. Call this commodity "withheld pollution," or "withholding," W. Then $J \equiv W$ and all the same marginal conditions apply as with $J \equiv N$. Assume for the time being that the level of output from which pollution will be withheld is known and accepted by all parties. This is the noninternalized level $X_P = Z$, which obtains when $P_P = 0$. Then

$$X_W = Z - X_P . \tag{13}$$

Since Z is a given constant,

$$\frac{dX_W}{dX_P} = -1 . \tag{14}$$

Internalization by bribery can be produced by commodity W in the general model with $J \equiv W$, a plus sign before P_W in (1), and a negative sign before P_W in (3) to give

$$P_W = -P_A \frac{\partial X_A}{\partial X_W} = P_B \frac{\partial X_B}{\partial X_W} . \tag{15}$$

Now, as a consequence of (14), our previous equilibrium with P_P can be turned into an equilibrium with P_W:

$$P_W = P_A \frac{\partial X_A}{\partial X_P}\bigg|_{X_P=S} = -P_B \frac{\partial X_B}{\partial X_P}\bigg|_{X_P=S} = P_P = K. \quad (16)$$

The marginal conditions of general equilibrium with "withholding" are identical but of opposite sign to those with pollution at the same level of output $X_P = S$. Total profits with bribery are

$$\pi_A = P_A X_A + K(Z - S) - wL_A - rC_A = KZ \quad (1b)$$

$$\pi_B = P_B X_B - K(Z - S) - wL_B - rC_B = -KZ. \quad (3b)$$

Writers in the Coase tradition typically hold that the lump sum transfer KZ shown in (1b) and (3b) as compared with (1a) and (3a) is of distributional significance only (ignoring, as we do, indirect effects on the structure of demand).

4. Critical evaluation

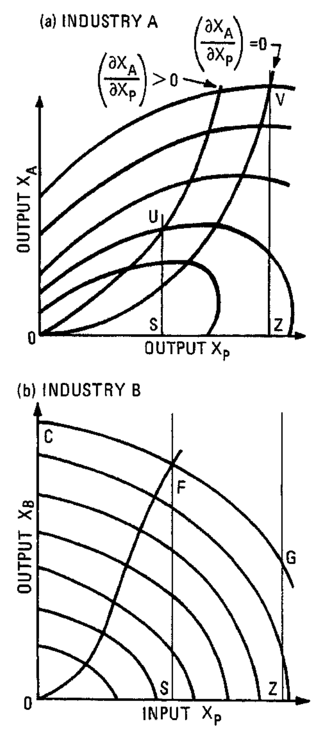
■ A statement of the total-profits anomaly appears in Bramhall and Mills.[11] Referring to industry B, they hold:

> Under the payments scheme [compensation], profits will be larger than they would have been in the absence of intervention, and under the fees scheme [bribery] profits will be smaller than in the absence of intervention. On the usual assumptions about entry and exit, entry will take place in the former case and exit in the latter case.

Wellisz[12] had previously made the point that for the Coase mechanism to hold, it is necessary to postulate nontransferable resources with Ricardian rents. We shall investigate the implications of transferable resources.

FIGURE 2

PRODUCTION–EXPANSION CURVES



☐ **The compensation case.** Production-expansion curves are shown in Figure 2 for the compensation case. The purpose of the curves is to show that the adjustment process is smooth, continuous, and follows conventional economic principles with compensation, in contrast to the situation we shall find with bribery. Figure 2 also gives information useful for the analysis of the bribery case and, in fact, can be reinterpreted for a bribery regime, though most of such reinterpretation will be left for the reader after the difficulties of bribery have been presented.

Figure 2(a) gives transformation curves (concave to the origin) for outputs A and P in industry A, each curve subject to a fixed resource constraint, which, in this case, is a real fund available for capital and labor at wage rates and interest rates fixed elsewhere in the economy. The transformation curves include positively sloped segments which imply that commodity A and pollution P outputs expand simultaneously over a part of the range. If there were not a positively sloped segment of each curve, there would be no pollution output in the first place. With strictly joint products, the transformation curves would collapse to a single ray from the origin, each point along which would correspond to different resource inputs, as well as different outputs. The slopes of the transformation

[11] In [3], p. 616.

[12] In [15].

curves at each point correspond to price ratios and represent isoprofit loci.[13]

Two expansion curves are shown, one labeled $\left(\frac{\partial X_A}{\partial X_P}\right) = 0$, the other labeled $\left(\frac{\partial X_A}{\partial X_P}\right) > 0$. Since industry A obtains revenue from output A, but not from P, the only points of interest are on the positively sloped parts of the transformation curves to the left of the expansion curve $\left(\frac{\partial X_A}{\partial X_P}\right) = 0$. This last represents, of course, the expansion path that industry A would take in the absence of any charge assessed for pollution: $P_P = 0$. Compare equation (10). To relate Figure 2(a) to Figure 1, the equilibrium points $X_P = Z$ and $X_P = S$ are shown. These correspond to points V and U, respectively, in Figure 2(a).

Figure 2(b) is constructed in the same way. The curves concave to the origin show transformation trade-offs of output B and input P with alternative quantities of fixed total resources. There are no positively sloped parts of these curves. Input P retards the production of output B and the latter retards the assimilation of P, each over the entire range. A possible expansion path of industry B to point F, the compensation equilibrium, is shown. With demand and supply fixed, the transformation curves are also isoprofit curves with slopes equal to price ratios.[14] Looking back to the origin from point F, the

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[13] The slopes of these curves can be found as follows. First, note that the marginal profits from commodity A are given by

$$\frac{\partial \pi_A}{\partial X_A} = P_A - P_P\frac{\partial X_P}{\partial X_A} - w\frac{\partial L_A}{\partial X_A} - r\frac{\partial C_A}{\partial X_A}. \quad \text{(i)}$$

If we define

$$\alpha_A = P_A - w\frac{\partial L_A}{\partial X_A} - r\frac{\partial C_A}{\partial X_A}, \quad \text{(ii)}$$

it can be shown that

$$\lim_{\alpha_A \to P_P \frac{\partial X_P}{\partial X_A}} d\pi = 0. \quad \text{(iii)}$$

Rearranging (i) with zero marginal profits then gives

$$\frac{\partial X_P}{\partial X_A} = \frac{P_A - w\frac{\partial L_A}{\partial X_A} - r\frac{\partial C_A}{\partial X_A}}{P_P}, \quad \text{(iv)}$$

which expresses the slopes of the production transformation curves at all equilibrium values of the indicated parameters and marginal conditions. Since $wL_A + rC_A$ is constant for any given contour of Figure 2(a), $\frac{\partial X_P}{\partial X_A} = \frac{dX_P}{dX_A}$ and the slopes shown in (iv) are reciprocals of the slopes shown in Figure 2(a).

[14] The slopes of the transformation curves shown in Figure 2(b) can be understood by reference to exactly the same kind of relationships described in note 13, above. Thus, marginal profits from commodity B are given by

$$\frac{\partial \pi_B}{\partial X_B} = P_B + P_P\frac{\partial X_P}{\partial X_B} - w\frac{\partial L_B}{\partial X_B} - r\frac{\partial C_B}{\partial X_B}. \quad \text{(i)}$$

and by exactly analogous reasoning, it can be shown that with zero marginal

$$\frac{\partial X_P}{\partial X_B} = \frac{-P_B - w\frac{\partial L_B}{\partial X_B} - r\frac{\partial C_B}{\partial X_B}}{P_P}. \quad \text{(ii)}$$

transformation contours represent higher and higher levels of marginal and average profits that could be achieved by a contraction of the industry with parametric increases in prices P_B and P_P.

No problems of adjustment are presented by the expansion curves in a compensation regime. Industry A can simultaneously expand or contract X_A and X_P in all combinations. Industry B can simultaneously expand the output of X_B and the input of X_P, for both of which it receives compensation along a common expansion curve. A reduction in demand consists of moving the positively sloped curve to the left in Figure 1; an expansion, to the right. Symmetrical movements of the negatively sloped supply curve produce expected results in the compensation price. Stability conditions are conventional, as noted in Section 2.

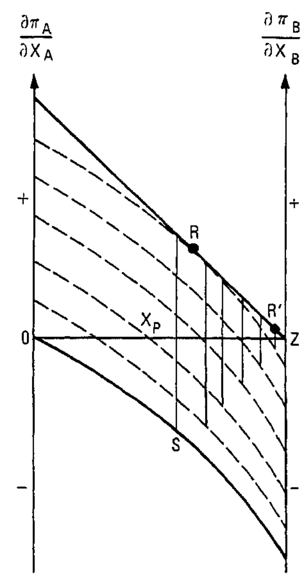
☐ **The bribery case.** Consider the situation with bribery. Industry A may expand, but it is not clear what will be produced. With Z held constant, $\frac{\partial X_A}{\partial X_W} < 0$ is a property of all expansion curves for industry A. See Figure 2(a), which is consistent with $\frac{\partial X_A}{\partial X_P} > 0$ and equation (14). One solution is to drop equation (14) and assume that witholding is sold from some level of $X_P > Z$. Whether this is a possible result depends on B's willingness to believe that A would, in fact, produce pollution at a level greater than Z. Point Z represents A's noninternalization optimum. Expansion in industry A might take place by balancing losses from A and W at the margin until the total profits in industry A are zero, but economic theory gives us no guidance as to whether or by what expansion path this will be done. In Figure 2(a), marginal profits are zero at point U, though total profits are KZ. See equations (15) and (1b).

The difficulty arises from a conflict between marginal and total profits. Marginal profits are zero at $X_P = S$ with bribery because industry A is being paid the marginal cost of curtailing pollution which, even with variable proportions, means a reduction of output A. Coase emphasized marginal profits; Bramhall-Mills, total profits. Total profits cannot help influencing the adjustments, but when there is a conflict between total and marginal profits, the outcome is a behavioral question. Stability is not assured, even if we assume that B has infinite resources with which to pay bribes.

Now, let us assume away instability in industry A. Assume that new competition is prevented by one means or another from entering industry A and that demand and cost conditions remain as previously given for A. Long-run contraction of X_B will raise the price P_B and result in higher marginal profits $\frac{\partial \pi_B}{\partial X_B}$. A bribery equilibrium might be established if P_B is raised high enough to offset the lump sum transfer. Whether this will happen depends on a complex set of circumstances. See Figure 3, which is a reproduction of Figure 1 with the right-hand axis reversed in sign. The left-hand axis remains as

FIGURE 3

BRIBERY EQUILIBRIUM



With $wL_A + rC_A$ constant, $\frac{\partial X_P}{\partial X_B} = \frac{dX_P}{dX_B}$, and hence the slopes in (ii) are the reciprocals of those shown in Figure 2(b).

before. The dotted lines show upward shifts in marginal profits to industry B as contraction takes place.

A total profits equilibrium is reached by B if some positive level of marginal profits results in zero total profits with bribery. Such an equilibrium is shown at point R. The reader can verify that if the curves were folded over with negative profits increasing upward as in Figure 1, the supply-demand "equilibrium" would move down the curve $\frac{\partial \pi_A}{\partial X_P}$ versus X_P. The vertical lines indicate points of bribery "equilibrium" in the process. Points R and R' are alternative equilibria. At R', marginal profits are negative. At R, they are positive. Industry B shifts discontinously from R' to R because at this point its demand curve has moved far enough upward to make R available. At R, industry B is receiving high enough marginal profits from sales of commodity B to pay the bribe and break even in the long run.

The above result, however, is sensitive to the shape of the curve $\frac{\partial \pi_B}{\partial X_B}$ versus X_P. If this curve is less bowed than $\frac{\partial \pi_A}{\partial X_A}$ versus X_P, equilibrium will be at either $X_P = Z$ or at $X_P = 0$. In the former case, no bribery is paid; industry B is absorbing pollution and earning high enough marginal profits to stand the real loss and break even in total profits. In the latter case, industry B buys off all pollution it would otherwise have received from A. The relevant quantity X_P received by B depends on the size (level of activity) in B as well as A. Pollution is a private good in the present context. This does not change the analysis but means that the scale on the horizontal axis in Figure 3 (and other figures) should be changed as the size of industry B (or A) changes.

To this point, only the problems of independent adjustment in A and B have been considered. Interdependent adjustment is complicated by uncertainty about the level of Z from which withholding is measured. Knowledge and agreement on this level would seem unlikely in a dynamic context.[15]

☐ **Conclusions.** It is possible that a stable total profits equilibrium of bribery might be achieved in a dynamic context; but the requirements, as described above, make it implausible. These requirements include: agreement between A and B on the value of Z from which withholding is to take place; demand and supply curves for withholding that have the right relative bow to permit a tangency solution as in Figure 3; and some part of B's bribery contraction curve with positive total profits, and these profits high enough to pay the bribe. This last condition depends on the relative sizes of industries A and B. Size affects the relative prices for conventional commodities A

[15] Kamien et al. [9] discuss a different kind of dynamic adjustment. They do not consider the problems discussed above, but analyze the case where industry A might adjust due to such normal causes as increasing demand for output A. Their work conforms to tradition in assuming a single valued function $X_P = f(X_A)$ with X_A independently produced. They consider the case where Z is not known but bribery is based instead on the quantity of X_P that is produced and removed by treatment. With the decision rule for bribery based on the amount treated rather than the amount withheld, they find both X_A and X_P produced in greater amounts than with compensation.

and B and also the internalization price P_W. Finally, there is the conflict of marginal and total profit conditions in A. B may find it possible, through contraction and increases in marginal profits in other lines, to pay the bribe. But A will be receiving a lump sum transfer beyond returns at zero marginal profits, which can only be offset by expanding to negative marginal profits levels elsewhere as long as the bribe is received and total profits are above normal.

Do these results depend on the reference base from which we started, viz., zero profits in industry B in the absence of any pollution? Such a base is entirely proper for the linear homogeneous production functions assumed. But let us relax the assumption of linear homogeneity. What are the conditions that would keep total profits at the zero level in equations (1b) and (3b) with K, S, and Z also as variables? The obvious answer is that somehow the effect of the lump sum transfer must be offset, or approximately offset, by the other transactions in these industries when marginal conditions are satisfied. Strict linear homogeneity may not characterize very many production functions, but it probably becomes closer than would a pair of lump sum production functions geared to produce deficits in A and surpluses in B so that they could be offset by bribery transactions.

It is interesting to note that difficulties of a qualitatively similar sort are encountered in marginal cost pricing for increasing returns industries, though in the increasing returns case, the problem arises from physical production conditions. In the bribery case, it arises from a lack of correspondence between physical and financial conditions. Bribery would match a linear homogeneous physical production function with financial relationships that cannot lead to exhaustion of product.

Compensation, in contrast, creates no such distortions but produces conventional market adjustments and stable equilibria.

5. Some related issues

■ **Blackmail.** Professor Coase expressed concern that if compensation were paid, the damaged party would intensify his activities so as to justify the award of greater damages.[16] The same fear was expressed by Kneese in an earlier work,[17] in the situation where a member of industry B threatens to locate downstream of a firm in industry A. Either way, the latter is faced with making more compensation payments.

The fear is groundless in a competitive setting. The Coase version has our industry B shifting toward more than optimal absorption of waste, which, of course, is in conflict with economic rationality. The Kneese version can be resolved by asking whether B is moving toward or away from optimal adjustment. If B could make a profit with the competitive level of costs and prices, including compensation, then B's locating at that point is socially desirable. It is then A whose operations are subject to question from the standpoint of a welfare maximum. If not, then A has nothing to fear.

Needless to say, a competitive solution is not to be expected in all cases. Market structures are not perfect; nor is knowledge a free

[16] See [5], pp. 32–33.
[17] See [10], p. 58.

good. Bilateral monopoly and/or imperfect knowledge can make blackmail possible. But blackmail then becomes, in the relevant sense, another name for market imperfection and is not unique to the process of internalizing through compensation. Those who believe bribery to be viable could equally well refer to blackmail possibilities for this case and, in fact, Kneese and Bower use the blackmail argument as a reason for recommending against bribery.[18]

□ **Third party pricing.** Third party pricing refers to the institutional arrangement where a third party, presumably a Public Authority, sets pollution charges and supervises the conduct of any internalizing transactions. In many contexts, the Public Authority also conducts waste treatment.

Kneese and Bower recommend that the Public Authority collect a tax but pay no subsidy, on the ground that completing the transaction would "lead to inefficient longer-term adjustments."[19] They state, citing Boyd:

> If . . . the right to the use of an asset (or resource) is made contingent upon engaging in a particular activity, and the right to the use of the asset given free to parties engaging in that activity, excessive activity in that line will be generated.[20]

Compensation and bribery are viewed symmetrically, as by Bramhall and Mills.[21] There is the additional twist that the right to use or not use the waterway for waste removal is treated as an asset. This point of view is made clearer in another passage by Boyd.

> The economic maximization model presented here treats the river basin as a multiple-product natural asset. The products of this asset are flows of two types of service, a vector of *waste removal* services and one of *water quality* services. The quantity of the latter services available at a given location depends on quantities of the former consumed at upstream points.[22]

The implied course of action is to charge a rent to both the waste disposer and the quality user. This treats the river facilities as a common asset the use of which should be rationed. It can easily be shown that rationing is quite a different process from internalization. The difference is in the sign that precedes the terms in the objective functions (1) and (3). Labor and capital inputs are being rationed to both industry A and industry B. Well-known first-order conditions require that the marginal value products of each be the same in all uses and equal to the wage rate and interest rate, respectively. In contrast, pollution effects enter (1) and (3) with opposite signs. A and B are on opposite sides of the market in which the pollution externality is to be internalized.

One of the implications of the foregoing is that ownership must be functionally identified with the commodity to be rationed (or discommodity to be disrationed). Decentralized decision-making is possible if property "rights" (responsibilities) are forced on industry A so that if pollutants produced by A were received by B, compensation would be due the latter and B would become "owner." That this

[18] In [11], pp. 104–5.

[19] *Ibid.*, p. 100. The word "subsidy" is theirs. It has inappropriate connotations for an internalization payment.

[20] *Ibid.*, p. 87.

[21] In [3].

[22] [2], pp. 199–200. Italics are in the original.

is not institutionally impossible is suggested by the contemporary existence of waste removal firms and enforced ownership of wastes, particularly of solid wastes in the form of trash, where payment for removal takes the form of compensation to the remover. In the river basin case, we found that the true rationing problem was not of river capacity but of downstream removal capacity.

□ **Public goods.** The logic of private goods analysis is equally applicable to public goods such as aesthetic and recreational damages. As long as partial equilibrium models are used, the optimum level of pollution and the compensation price can be determined from the vertical summation of (positively sloping) demand curves of damaged public goods recipients.

An unexpected windfall results from the reversal of the transaction, as required by compensation. In contrast to the situation with positive public goods, where the prospect of paying one's demand price gives an incentive to conceal demand, there is with negative public goods and compensation the incentive to reveal demand.The Public Authority is likely to have ample information volunteered from damaged parties (and from some not damaged). Its problem would be more that of establishing authenticity and accuracy.

The last is a form of the blackmail problem. One way to deal with it is to make compensation in the form of additional treatment to remove more pollution. Instead of paying compensation in financial terms, the control of blackmail might force the payment of compensation in kind. Only authentic damage receivers will benefit from having additional pollution removed.

It is obvious that payment in kind by the above system introduces inefficiencies. By the definition of optimum treatment as the supply-demand equilibrium, there will be nonoptimal (excessive) treatment. The reader is left to catalog other sources of inefficiency. Nevertheless, compensation gives us another approach to the problem of public goods pricing (albeit only for negative public goods). We are probably no further from an optimal translation of theory into practice with compensation than we are with conventional public goods pricing.

Glossary of notations

■ Variables

- C Quantity of capital.
- L Quantity of labor.
- P Price.
- r Return on capital.
- w Wage rate.
- X Quantity of commodity.

- λ Lagrange multiplier.
- π Profits.

□ Subscripts and superscripts

- A Industry or commodity.
- B Industry or commodity.

J All-purpose subscript that can take on meaning of N, P, or W.
N Nectar.
P Pollutant.
W Withheld pollutant.

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