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In his invitation to contribute to this symposium on the Coase controversy, the editor of this journal remarked, ". . . Coase initiated a very intensive debate on the neutrality of property rights as regards resource allocations in 1960." This is indeed true and as it happened, a fairly casual set of remarks in a publication by one of the present authors (Kneese) became one epicenter of this debate. The remarks were contained in a publication considering, among other things, the traditional Pigovian solution of taxing an externality-causing activity, in this case the discharge of water pollutants. The question arose as to whether a system of subsidy payments (later termed bribes in the literature) could be made equivalent to charges or taxes as regards allocative effects.[1]

This question has some pertinence since many governments have displayed a fondness for subsidizing pollution control activities. In terms of property concepts, the tax solution could be taken to imply that rights to the waste assimilative capacity of the environment are publicly held and subsidies that they are privately held by the waste dischargers. The equivalence is not exact since in the bribes and charges case there is no exchange of money between the dischargers and specific receptors. In the charges case payments go to the "public in general" rather than to specific receptors. In the bribes case money to make the payment comes from "the general fund." Accordingly, if we wish to relate these schemes to property concepts, we must in the case of charges conceive of the general public, rather than specific users owning the resources. In the bribes case the dischargers can be thought of as owning the resource and the government acting in behalf of other users.

It was concluded that in principle bribes could be so arranged that the effects on *opportunity* costs and hence on allocative decisons would be similar to those of taxes. The procedure would be to make payments to the waste discharger per unit of reduction of waste discharge. But it was pointed out that the required payments scheme bore little resemblance to the subsidy programs actually undertaken by governments and that the information requirements of an optimal

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1. A. Kneese, The Economics of Regional Water Quality Management (1964).

payment system were so extreme as to make it little more than an intellectual curiosum. Specifically, it was said that:

> . . . finally, and most important, the payments procedure encounters particularly difficult administrative problems. For one thing, an industrial enterprise may find it profitable to adopt processes which generate much waste in order to be able to accept payment for reducing discharge. Problems are compounded when industrial location decisions or decisions to enter or leave an industry are involved. Payments would have to be continued to a firm even if it chose going out of business as the best means of reducing its waste discharge. Furthermore, payments would have to be made to firms who would locate in the region if the payment were not available.[2]

Since the bribes approach was regarded as essentially impossible to implement, the remainder of the discussion focused mostly on effluent charges and direct government investment as means of managing water quality efficiently.

But the statements made about the bribes-versus-charges question subsequently stimulated considerable comment in the literature. A major article by Kamien, Schwartz, and Dolbear[3] further developed the matter of how bribes might be arranged when the administrative authority does not know how much would in fact have been discharged if no bribe had been paid—a matter raised in the above quotation. They referred to it as the "zero point question." Without knowledge of what discharges would have been in the absence of intervention, they assume that the control agency bases its payment on the amount by which the waste producer reduces his discharge below the waste *actually* produced, rather than the amount he *would have* produced in the absence of intervention. The authors show by a detailed and rigorous analysis that this payments scheme will induce the profit-maximizing waste producer to produce more waste than he would have under the correctly specified charge scheme (i.e., one based upon the amount he would have produced in the absence of intervention) and that he may produce more than he would have in the absence of any intervention. They conclude that this is a basic asymmetry between bribes and charges.

The Kamien, Schwartz, and Dolbear contribution was a useful elaboration of one of the points raised in the above quotation. But other commentators claimed that there is a more fundamental asymmetry between bribes and charges which was overlooked in the

2. *Id.* at 58.

3. Kamien, Schwartz, & Dolbear, *Asymmetry Between Bribes and Charges*, 2 Water Resources Research 147-57. (1966).

above cited book and that the conclusion about symmetry stated there was consequently wrong.[4]

Bramhall and Mills make the point succinctly, and a quote from their article serves well to put the critics' case:

> The point that is important for long run analysis is that the resulting profit levels . . . differ. . . . Under the payments scheme, profits will be larger than they would have been in the absence of intervention, and under the fee scheme 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. Entry will lower the price of his product relative to prices of other products, and exit will raise it. Thus, relative prices will, in the long run, be different under the payments scheme rather than under the charge scheme. Since relative prices will differ, the choice between the two schemes is partly a matter of efficiency and not, as Kneese concludes, entirely a matter of equity.[5]

Since the critics made quite a point of the assertion that the analysis neglected differences in profit levels (i.e., impacts on average costs of actual, potential, and past producers in the industry), an effort was made to elaborate the exposition in a subsequent revision of the book in which the symmetry argument was originally made.[6] After supplying a graphical and numerical description of how marginal costs are affected by bribes and charges, it was pointed out explicitly that average cost would be affected similarly by bribes and charges because both become an opportunity cost of production—but only if the bribes system is designed in a very particular way.

We think it will be helpful to the reader to reproduce the pertinent text, leaving out the numerical example.[7]

> We believe that a system of payments, or "bribes" as they have recently been termed in the literature, could in principle achieve the same result as an optimal charges scheme, despite some recent statements to the contrary.
>
> Assume that a profit-maximizing firm has an incremental production cost curve as indicated by *MC* in Figure 16, that the price at which the firm can sell the commodity it produces is given, as indicated by the curve *D*, that the *only* way the firm can

4. *See, e.g.*, Bramhall & Mills, *A Note on the Asymmetry Between Fees and Payments*, 2 Water Resources Research 615-16 (1966); Freeman, *Bribes and Charges: Some Comments*, 3 Water Resources Research 287-98 (1967).

5. Bramhall & Mills, *supra* note 4.

6. A. Kneese and B. Bower, Managing Water Quality: Economics, Technology, Institutions (1968).

7. *Id.* at 101-04.

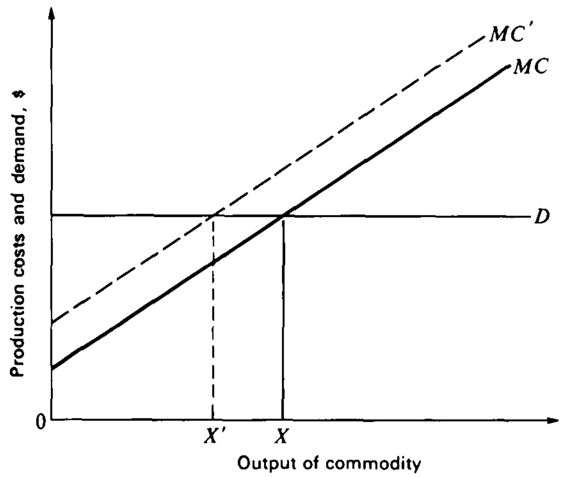

Figure 16

diminish the amount of a residual substance which it discharges into a stream is to reduce production, and that residual waste per unit of output is a constant. If a regulatory authority imposes a unit charge on the effluent of the firm, the incremental production cost function will shift upward by the amount of the charge per unit of output (i.e., charge per unit of effluent times effluent per unit of output) from *MC to MC'*.

On the other hand, if the regulatory authority offers to pay the same amount per unit for reducing waste discharge, the incremental cost function will still be *MC'*. A firm rationally trying to maximize its profits will view the payment as an opportunity cost of production because waste discharge is, by assumption, a straightforward function of production.†

. . . .

The question may well be raised whether in terms of longer-term adjustments, i.e., a firm's decision to enter or leave an industry or to expand or contract production capacity, the effect may not be different. The answer is in principle "no," but great informational and administrative difficulties emerge if the payments route is adopted. These are discussed later.

In Figure 17, *AC* indicates the long-run average cost curve of a plant. This curve indicates the average costs of producing various levels of output (including an average return on investment) under conditions where a plant can be designed to produce a given output at least overall cost. If the price is as indicated by *D*, the firm would construct a plant for which costs were lowest at output level *X*. This is the relationship which would tend to prevail in

†The assumption that waste discharge is a linear function of output was released in later parts of the text, but this is not necessary for present purposes.

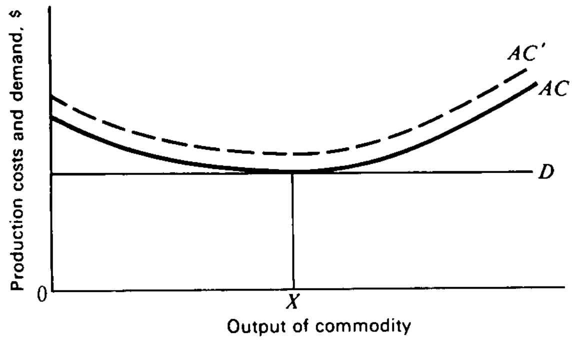

Figure 17

equilibrium in a competitive industry. A charge on effluent per unit would raise the average cost function by the same amount for each unit of output. Consequently, the new average cost curve would be a simple vertical displacement of the old, as shown by *AC'*. A payment would have the same effect because it is an opportunity cost. The price of output must be high enough to cover the amount of the available payment as well as costs of production (including a normal return on investment), if it is to be worthwhile for the firm to produce an additional unit. In effect, the plant's cost curve (reflecting the value of all foregone opportunities if production is carried on) is raised by the amount of the payment if the payment is available to it whether it is producing or not.

. . . .

The effects of waste disposal costs on prices, location, and decisions to enter or leave an industry will usually be small, because these costs are generally quite low relative to other costs of production and because the firm has the option of treating or otherwise modifying final waste output.

Decisions on location and/or industry entry or exit, however, have a major effect on the administration of a system of payments. Payment must be continued after shutdown of a plant, if the procedure is to have the desired results. While this might be manageable, serious problems would occur if a shift in demand for the product should increase the potential profitability of the plant, or if other dynamic adjustments should take place. Moreover, plants might introduce processes that produce a greater quantity of waste in order to obtain payment for reducing waste.

Even more perplexing would be the handling of proposals for new industrial locations. The administrative authority would have to stand ready to make payments to industrial plants which never do locate in the area but which would do so if a payment reflecting the costs their effluents would impose were not made. Payments on this basis would of course be an open invitation to

> extortion. If charges were levied, however, the authority would only have to provide the prospective firm with an estimate of the unit charge to be placed on its effluent.

As this quotation implies but perhaps does not point out clearly enough, the central problem is how to make the "shadow" average costs of potential and past producers in an industry (region) reflect the external costs of production. If one sticks to a pure bribes scheme, this can be done only by arrangements whereby the bribe is not made contingent on actual participation in the industry (region). A consequence of this (plus the "zero point" problem) is that an optimal bribes scheme would require information about the full general equilibrium solution for the entire economy. Several authors have demonstrated that under some plausible conditions much less information than that is needed to implement a charges system.[8]

We could let the matter rest here except that we are apparently far from having convinced everyone. In both conversation with other economists and in the literature, the complaint is still voiced that the argument is invalid in the long run, because it neglects effects on average costs and profits. For example, Lambelet has written about the above reproduced discussion: "The source of confusion seems to be that they disregard the fact that a subsidy lowers the average total cost curve while a tax increases it. . . ."[9]

RESULTS FROM A GENERAL EQUILIBRIUM MODEL

We might be forgiven for accusing, in a peevish mood, some of the critics of the symmetry argument of reading what is in their head, not what is on the paper. But more soberly, it is clear that the assumptions have not yet been set out straightforwardly enough, and the argument has yet to be stated with sufficient clarity and rigor. We try to do this in the appendix of this paper. The device used is a simple general equilibrium model of a competitive economy. While simple, it contains all the main relationships usually included in such models and does not require any unusually strong assumptions.

As we mentioned, the details of the model are presented in the appendix but we do want to state the main conclusions here. With the

8. For an excellent recent discussion *see* Baumol, *On Taxation and the Control of Externalities*, 62 Am. Econ. Rev. 307 (1972).

9. Lambelet, Recent Controversies Over Environmental Policies, University of Pennsylvania, Department of Economics, Discussion Paper No. 237 (May, 1972); *see also* Tybout, *Pricing Pollution and Other Negative Externalities*, 3 The Bell J. of Econ. & Management Sci. 252-65 (1972); The Instruments for Environmental Policy, a paper presented by W. Baumol & W. Oates at the Conference on Economics of the Environment sponsored by the Universities–National Bureau Committee for Economic Research and Resources for the Future, Inc. in Chicago, Nov. 10-11, 1972.

help of the model three different types of situations are examined: (1) a pure charges strategy, (2) a mixed strategy involving both bribes and charges, and (3) a pure bribes strategy. It is shown that all three can be made equivalent in terms of allocative effects. In the case of the mixed strategy, taxes are levied on new firms entering an industry (region) and subsidies are paid to those already in it. But for this strategy to be equivalent to the pure tax strategy the subsidy must continue to be paid to firms who leave because of the internalization of opportunity cost, but who would not do so if payment were made contingent upon continuing in the activity. In the pure bribes case, bribes must be extended symmetrically to firms which do not enter but would do so if payments of the bribe were made contingent on entry. These are the same results previously deduced from a less rigorous analysis.

CONCLUSION

If we have finally convinced our readers that one can envision conditions in which bribes and charges achieve a similarly efficient result, we nevertheless regard it as rather a hollow victory. The information needed to administer an optimal system of bribes, or some reasonable approximation of it is, for all practical purposes, impossible to get. The main practical purpose for going through such an exercise as we have just done is to reveal how far short the actual subsidy schemes adopted by many governments fall from being able to achieve an efficient allocation of resources. All the subsidy arrangements with which we are familiar provide support for the construction of waste treatment facilities and do not make payments for the actual reduction of waste discharges. By itself, such support provides no incentive at all to reduce waste discharges. Even if the government paid the entire cost of building a waste treatment facility, the discharger would still be indifferent as to whether to use it if there is no penalty for the discharges he actually makes. Accordingly, the subsidies must be accompanied by an elaborate enforcement system.

Furthermore, subsidies for waste treatment plant construction bias the selection of technologies in a particular way. In most industrial processes, by-product recovery and other process adjustments can greatly reduce waste generation and usually curb discharges at lower cost than exclusive reliance on treatment. But the provision of subsidies for treatment biases the cost comparison.

To move the subsidy schemes which now exist in the direction of efficiency would require, to begin with, rewarding the actual reduction of waste discharge in a technologically neutral way. Then

one could worry about distorting long-run effects on profit margins. But in terms of attaining efficiency in an actually functioning program, the results of more than a decade of theoretical and empirical research since Coase's article appear to point right back to the Pigovian approach.

APPENDIX

A GENERAL EQUILIBRIUM MODEL FOR ANALYSIS OF BRIBES AND CHARGES

The model economy is assumed to be perfectly competitive. There are n different commodities and services. The set of potential producers is denoted by A, and each producer is denoted by an index k. The price vector is p. The set of producers actually operating in a market when the price vector is p is denoted by K(p).

We assume that all individual production sets are strictly convex so that the supply functions are indeed functions and not correspondences.[10] We follow the usual convention and regard outputs (including waste products as positive quantities and inputs as negative quantities. The supply function of producer k is written $x^k(p)$. The total supply is

$$x(p) = \sum_{k \in K(p)} x^k(p).$$

The profit for producer k is

$$p^T x^k(p), \qquad (p^T x \text{ denotes the inner product of p and x})$$

There are H consumers in the economy. Each consumer owns a vector of resources w^h and a share in firm k's profit α_k^h. The wealth of consumer h is then

$$R^h = p^T w^h + \sum_{k \in K(p)} \alpha_k^h p^T x^k(p).$$

Utility maximization gives the demand functions (we assume strictly quasi-concave utility functions so that no correspondences will appear)

10. Baumol and Bradford have shown that externalities between different production activities will in general create non-convexities in the aggregate production set. Baumol & Bradford *Detrimental Externalities and Non-Convexity of the Production Set,* Economica (May, 1972). This does not apply to our model because the externalities considered here affect only the consumers. Moreover, Starrett has pointed out that even if there are negative externalities between different producers, the production sets that are relevant to a discussion of charges and bribes are still convex. D. A. Starrett, Harvard Institute of Economic Research Discussion Paper No. 115.

$$D^h(p,R^h,Y),$$

where Y is a vector of environmental qualities (if environmental quality affects not only the satisfaction of consumers but also the production possibilities of the firms, then Y should also appear as an argument in the supply functions, whereupon convexity may be violated. If it is not, the following argument applies.).

The total demand is then

$$\sum_{h=1}^{H} D^h(p,R^h,Y).$$

Private equilibrium is defined by

$$z = \sum_{k \in K(p)} x^k(p) + \sum_{h=1}^{H} w^h - \sum_{h=1}^{H} D^h(p,R^h,Y) \geq 0$$

$$K(p) \subset \{k \in A;\ p^T x^k(p) \geq 0\},\quad a/K(p) = \{K \in A;\ p^T x^k(p) \leq 0\}$$

(The symbol A/K(p) denotes the set theoretical difference between A and K(p).)

$$R^h = p^T w^h + \sum_{k \in K(p)} \alpha_k^h p^T x^k(p), \qquad h = 1, \ldots, H.$$

The first condition is the short-run equilibrium condition that the excess demand for no service and no commodity must be positive. The second condition is that no firm operating in any market has a negative profit and that no potential producer can make positive profit by entering some market. The third condition is simply the definition of the wealth of consumer h.

For some commodities the excess supply will be strictly positive, and this excess supply must be disposed of by discharging it into the environment. This is in particular true for waste products for which there are no demands at all. This use of the environment as a dumping ground will deteriorate the quality of the environment. We assume that the relation between the environmental qualities and the discharge of residuals (or excess supplies) is given by the environmental interaction function

$$Y = F(z).$$

Next, assume that the society has an objective to prevent the vector of environmental qualities to fall below certain ambient standards, $\bar{Y}$:

$$Y \geq \bar{Y}.$$

In order to achieve this objective, the society may impose effluent

charges given by the vector q. For most goods the corresponding components in q will be zero, but for residuals which are harmful to the environment the corresponding components will be positive. The effluent charges will change the price vector from p to p – q, meaning that commodities which in private equilibrium have a zero price now have a negative price. The proceeds from the charges are assumed to be distributed in a lump sum manner to the consumers.

The public equilibrium is defined by

$$z = \sum_{k \in K(p\text{-}q)} x^k(p\text{-}q) + \sum_{h=1}^{H} w^h - \sum_{h=1}^{H} D^h(p\text{-}q, R^h, Y) \geq 0$$

$$K(p\text{-}q) = \left\{k \in A;\ (p\text{-}q)^T x^k(p\text{-}q) \geq 0\right\},\ A/K(p\text{-}q)\ \left\{k \in A;\ (p\text{-}q)^T x^k(p\text{-}q) \leq 0\right\}$$

$$R^h = (p\text{-}q)^T w^h + \beta^h q^T z + \sum_{k \in K(p\text{-}q)} \alpha_k^h (p\text{-}q)^T x^k(p\text{-}q), \qquad h = 1, \ldots, H$$

$$F(z) \geq \overline{Y}$$

The first condition says, as before, that excess demand must be non-positive. The second condition is exactly as in private equilibrium. The third condition now defines wealth as the value of resources, the share of profits and lump sum transfers or the proceeds from the effluent charges. The last condition is simply that the ambient standards must be met. We know that this public equilibrium has certain normative properties, in particular that the ambient standards are met at least social cost.

Let us now introduce bribes or subsidies. We will consider the following scheme for subsidizing the polluters. For each agent a vector of commodities and services is determined, and the agent is paid in accordance with the amount he is able to reduce his supplies in comparison to this vector. For a firm k there is thus determined a vector $\overline{z}_k$ and the firm is paid $q^T(\overline{z}_k - x^k)$ where x^k is the firm's actual supply vector (q is equal to the vector of effluent charges considered above). For commodities that are not in excess supply the charge is zero, and consequently the firm is not subsidized for reducing the supply of such commodities. The same is true for commodities that, even if they are in excess supply, are not harmful to the environment. It is natural to assume that $\overline{z}_f^k = 0$ for potential firms not operating in a market. If such a firm enters a market, it will not be subsidized but has to pay effluent charges $q^T x^k$. It is possible, however, to imagine situations where new firms should also be

subsidized, but in these cases the subsidy must not be contingent upon participation in the industry.

Similarly for consumers. The net supply of consumer h is $w^h - D^h$, and if the vector $\bar{z}_c^h$ is determined for him, he will be paid $q^T(\bar{z}_c^h - w^h + D^h)$. The total expenditures for this scheme are

$$S = \sum_{k\in K'} q^T(\bar{z}_f^h - x^k) + \sum_{h=1}^{H} q^T(\bar{z}_c^h - w^h + D^h)$$

$$= q^T\left[\sum_{k\in K'} \bar{z}_f^k + \sum_{h=1}^{H} \bar{z}_c^h - \sum_{k\in K'} x^k - \sum_{h=1}^{H} w^h + \sum_{h=1}^{H} D^h\right]$$

$$= q^T\left[\sum_{k\in K'} \bar{z}_f^k + \sum_{h=1}^{H} \bar{z}_c^h - z\right],$$

where K′ is the set of firms actually operating in a market with this subsidy scheme (K′ will be defined more precisely below). These expenditures are financed by lump sum transfers from the consumers, so that consumer h pays $\beta^h S$.

The wealth (or lump sum income) of consumer h is then

$$R^h = p^T w^h + \sum_{k\in K'} \alpha_k^h \Pi^k + x - \beta^h S,$$

where Π^k is the profit of firm k:

$$\Pi^k = p^T x^k + q^T(\bar{z}_f^k - x^k) = (p\text{-}q)^T x^k + q^T \bar{z}_f^k.$$

It is clear from this that if the firm is producing something, then its supply is determined from the same supply function as above, that is

$$x^k(p\text{-}q)$$

Obviously the same is true for the consumers, so that their behavior can be described as maximization of utility with prices p-q and lump sum income

$$R^h + q^T \bar{z}_c^h$$

The short-run equilibrium can now be characterized by

$$z = \sum_{k\in K'} x^k(p\text{-}q) + \sum_{h=1}^{H} w^h - \sum_{h=1}^{H} D^h(p\text{-}q, R^h + q^T\bar{z}_c^h, Y) \geq 0.$$

The set K′ depends on the precise way the subsidies are administered. If the subsidy ends if firms stop production, then there are incentives for the firms to remain producing and K′ will contain more producers than the corresponding set K(p-q) when effluent charges are used. In this case, the two approaches will differ with respect to resource allocation, and since the effluent charges scheme is efficient, bribes cannot be efficient.

On the other hand, if the subsidies continue after the firms have stopped production (as transfers equal to $q^T \bar{z}_f^k$ to the old owners), the subsidy will not have any effects on the incentives to stop production, and the outcome is the same as when effluent charges are used, except that the income distribution is different (it is however possible to choose the shares β^h in such a way that the income distribution is the same in the two cases).

We have thus shown that it is possible to construct a scheme of subsidies that is equivalent to effluent charges. This scheme consists of a subsidy per unit of waste discharge reduction in comparison to a predetermined level for agents that already are polluters and effluent charges for new firms. The subsidy must however continue to the owners of firms even after the firms have stopped their operations.

Moreover, if exclusive reliance is placed on subsidies, all potential entrants to the industry which would enter the industry if they had to do so to obtain the subsidy have to be subsidized. This includes firms which never come into being but would if the subsidy were made contingent on actually producing the product (i.e., discharging waste materials). In addition, if dynamic adjustments in demand or supply can occur, the condition becomes even more restrictive. In that case, subsidies must be paid to all firms which would come into being under all alternative price structures if the subsidy were contingent upon participation in the industry.