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Emissions Charge and Asymmetric Information: Consistently a Problem?

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This study calls into question the established view that lack of information on clean-up cost functions represents a serious problem in designing an optimal charge on polluting waste discharged by N point sources. In the standard case of "adverse-selection," a firm is shown to have an unbounded incentive to under-report marginal clean-up costs. However this result should be revised if the firm is required to behave "consistently" with its own reports. In the latter case, not only is the incentive to under-report marginal clean-up costs no longer unbounded, but it also becomes possible to identify the conditions in which such an incentive approaches zero.

1. INTRODUCTION

This study is a contribution to the ongoing debate concerning policies for control of point source pollution, within the framework of "adverse selection" originally discussed by Kwerel [3], and later generalized in the studies by Dasgupta *et al*. [2] and Spulber [4].

The standard version of the model considers N competitive firms discharging their polluting waste into the environment, for instance into a river. There is only one type of pollution and all discharge has the same impact on the environment, whatever the source. Each firm deterministically knows its own clean-up cost function. The level of each firm's discharge can be monitored at the source.[1]

The Regulator decides that a unit emissions charge should be used as a price incentive in order to obtain an optimal pollution level. Within the framework of partial equilibrium, the Regulator takes into consideration only the damages suffered by the victims of pollution and the clean-up costs incurred by firms.[2] But the Regulator, while being in a position to estimate the social damage function resulting from pollution, at least in the relevant region, has no information concerning the clean-up cost functions for the N firms. According to the typical logic of "adverse selection" problems, the Regulator is in a position to monitor the

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[1] Pollution control policies different from the emissions charge, considered in this paper, are required in the case of "non-point source pollution" (where it is technically impossible to monitor emissions at the source).

[2] Spulber [4] generalized Kwerel's analysis by considering a target function that makes it possible also to take into account the effects in the product and factor markets.

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results of clean-up activities of each individual firm, but does not know their ‘‘type’’: that is to say, it does not know the costs of such activities.[3]

In order to set an optimal unit emissions charge, the Regulator must acquire information from the firms concerning their clean-up costs. As is well known, the optimal unit emissions charge must equal the social marginal damage of pollution in its optimal conditions, whenever the latter equals the firms’ marginal clean-up cost. But the literature quoted at the beginning of this paper takes it for granted that ‘‘the government will learn no useful information by asking firms to report their pollution control costs when firms believe that the information will be used to set e (the rate of the charge) in a pure effluent charge plan’’. For ‘‘if a firm anticipates a pure effluent charge, it can be shown that given any clean-up cost function reported by the firm, and any cost functions reported by other firms, the firm would have been at least as well off by reporting a clean-up cost function with lower marginal costs for all levels of pollution output.’’ [3, p. 597]

The present paper shows that such a conclusion should be revised if the Regulator requires each firm to pay the optimal emissions charge based on the marginal clean-up cost function declared by the firm itself. If the firm is required to behave ‘‘consistently’’ with its own report,[4] then the incentive to under-report the marginal clean-up cost function is not ‘‘unbounded.’’ In this case, if it turns out that the marginal expected social damage function resulting from pollution does not increase too rapidly, and if at the same time the relative slope of the marginal clean-up cost function is not too elevated, then the firm’s report will foreseeably not be too distant from the truth. It follows that in the standard ‘‘adverse selection’’ case, designing an optimal emissions charge may be less problematic than previously feared.

2. SYMMETRIC INFORMATION

As already mentioned in the Introduction, we will consider a case of river pollution resulting from waste discharged by N firms. Each unit of polluting waste contributes to the same extent, whatever its source, to only one kind of pollution. Thus the pollution level X is equal to the sum of the units of polluting waste x_i discharged into the river by each firm i; that is $X = \sum_i x_i$.[5]

The Regulator is in a position to evaluate the damages caused by all possible levels of pollution; that is to say it can estimate the function of the expected social damage resulting from pollution $D(X) = D(\sum_i x_i)$. Let us suppose that this function increases by increasing increments, so that $D'(X) > 0$ and $D''(X) > 0$.

As far as clean-up costs are concerned, let $\bar{x}_i$ indicate the quantity of polluting waste discharged into the river by firm i, for $i = 1, 2, \ldots, N$, in the absence of any pollution control policy enacted by the Regulator. As compared to the *status quo*,

[3] If, in addition to agents’ intervention, ‘‘Nature’’ can also affect the firms’ clean-up cost function, then the problem takes on different characteristics, both *adverse selection* and *moral hazard* at the same time.

[4] In this study, discharge monitoring at the source (or an effective system of inspections and fines) makes it possible to ensure that the firm does not evade the charge, i.e., does not discharge more waste into the river than reported.

[5] More generally, the level of pollution can be considered to depend on the vector of waste discharged by the firms [2].

for each firm i it is possible to define the function of clean-up costs borne by the firm for labor and/or machine hours devoted to filtering, purifying, recycling, etc. its waste instead of discharging it into the river. Let $C_i(x_i)$ represent the minimum cost incurred by firm i, at a given state of technology, in reducing polluting waste from $\bar{x}_i$ to the level x_i. We will assume that this function is deterministically known to the firm and that in the region $0 \leq x_i \leq \bar{x}_i$ it decreases by decreasing decrements as the quantity of waste x_i discharged into the river increases, so that $C_i'(x_i) < 0$ and $C_i''(x_i) > 0$.

If complete information on the social damages function of pollution and on clean-up cost functions of firms is acquired, then the Regulator is in a position to set the unit emissions charge such that the following condition is satisfied,

$$t = D'(X^*) = -C'(X^*) = -C_i'(x_i^*) \qquad \text{for all } i, \tag{1}$$

where $C'(X)$ is the derivative of the aggregate clean-up cost function $C(X) = \min\{\sum_i C_i(x_i) \text{ s.t. } \sum_i x_i = X\}$.

With such a charge, each firm intending to minimize its total cost function $F_i(x_i) = t \cdot x_i + C_i(x_i)$, must choose the waste discharge level x_i^* that satisfies the first-order condition for an interior solution

$$t = -C_i'(x_i^*) \qquad \text{for all } i. \tag{2}$$

As can be seen, once all firms satisfy condition (2), condition (1) is also satisfied. The Regulator obtains the optimal pollution level $X^* = \sum_i x_i^*$. It is important to observe that once the Regulator has acquired the necessary information, when it calculates the optimal unit emissions charge t it also determines the optimal discharge level x_i^* for each firm i, as well as the optimal charge $t \cdot x_i^*$ that firm i must pay.

3. ASYMMETRIC INFORMATION

Let us maintain all previously stated assumptions, but let us now recognize that in effect the Regulator has no knowledge at all of the firms' clean-up cost functions. The function $C_j(x_j)$ is "private" information possessed by firm j. Assuming that firms cannot communicate with each other, but only with the Regulator, we have a typical Principal/Agent scheme with "adverse selection."

The Regulator asks each firm j to report its own clean-up cost function. Along with this request the Regulator also declares that the information thus acquired will be used, according to the rules set forth in the previous paragraph, to determine the optimal unit emissions charge t. In this context, each firm j must choose its own strategy: it must choose which clean-up cost function to report, while being fully aware that the Regulator will determine the "optimal" unit emissions charge on the basis of this report and of reports made by the other $N - 1$ firms (also taking into account the expected social damages function resulting from pollution).

The issue discussed in this paper is the following: is there in any case an incentive for firm j to report a clean-up cost function different from the real one?

Reflections proposed in current literature would appear to answer positively: each firm j has an "unbounded" incentive to report a clean-up cost function with a lower marginal cost than the real one, for each level of polluting waste. The demonstration of this assertion is considered to be trivial [3, p. 600].

In this section, I will show that if the Regulator requires the firms to pay their charge based on their own statements, actually forcing them to behave "consistently," then their incentive to under-report the marginal clean-up cost function is no longer necessarily "unbounded."

To demonstrate this assertion, the expedience of parameterizing the clean-up cost function of firm j can be used. Let p indicate this parameter. The clean-up cost function then becomes $C_j = C_j(x_j, p)$. Let us posit that for $p = p^\circ$ we have the *real* clean-up cost function $C_j^\circ = C_j(x_j, p^\circ)$. Let us moreover assume that a variation in parameter p induces a variation in the same direction affecting the absolute value of the marginal clean-up cost function for all levels of polluting waste x_j: since $-C_x^j(x_j, p) > 0$, we have $-C_{xp}^j(x_j, p) > 0$. The aggregate marginal clean-up cost function likewise depends on parameter p, so that $-C_{xp}^j(x_j, p) = -C_{xp}(X, p) > 0$, given the marginal clean-up cost functions reported by the other firms $i \neq j$.

Now it is possible to define the minimum value function of the overall cost of pollution control policy in firm j's calculations; that is to say

$$F^j(p) = t(p) \cdot x_j(t(p), p) + C^j\big(x_j(t(p), p); p^\circ\big), \tag{3}$$

where $t(p)$ is the unit emissions charge set by the Regulator on the basis of firm j's statement (given the statements by the other firms and the expected social damage function resulting from pollution), $C^j(x_j(t(p), p); p^\circ)$ is the *real* clean-up cost function (marked by parameter p°), and $x_j(t(p), p)$ is the optimal level of polluting discharge "consistent" with the clean-up cost function reported to the Regulator, implicitly determined by the first-order condition for an interior minimum of the function $\Phi^j(p) = t(p) \cdot x_j(t(p), p) + C^j(x_j(t(p), p); p)$; that is to say

$$t(p) = -C_x^j\big(x_j(t(p), p); p\big). \tag{4}$$

By differentiating (3) with respect to parameter p, collecting the terms, and substituting from (4), we have

$$\frac{dF^j(p)}{dp} = \frac{dt(p)}{dp} \cdot x_j(t(p), p) + \left[C_x^j\big(x_j(t(p), p); p^\circ\big) - C_x^j\big(x_j(t(p), p); p\big)\right] \frac{dx_j(t(p), p)}{dp}. \tag{5}$$

To study the slope of the minimal overall cost function of pollution control policy for firm j, we note in (5) that:

(i) the polluting waste level in the optimal "consistent" non-corner solution is $x_j(t(p), p) > 0$;

(ii) the unit emissions charge, in the Regulator's calculations, varies in direct relation with parameter p of the marginal clean-up cost function reported by firm j; that is to say [cf. 3, footnote 5]

$$\frac{dt(p)}{dp} = -\frac{D_{xx} \cdot C_{xp}}{D_{xx} + C_{xx}} > 0 \qquad \text{for all } p; \tag{6}$$

(iii) the optimal "consistent" polluting waste level in firm j's calculation also varies in direct relation with parameter p of the marginal clean-up cost function reported by firm j; that is to say

$$\frac{dx_j(t(p),p)}{dp} = -\frac{C_{xx}}{C^j_{xx}}\left(\frac{C_{xp}}{D_{xx}+C_{xx}}\right) > 0 \qquad \text{for all } p;^6 \tag{7}$$

(iv) finally, since the absolute value of the marginal clean-up cost is a direct function of parameter p, in (5) we have

$$\left[C^j_x\big(x_j(t(p),p);p^\circ\big) - C^j_x\big(x_j(t(p),p);p\big)\right] \gtreqless 0 \qquad \text{for } p \gtreqless p^\circ. \tag{8}$$

Therefore, on the right-hand side of (5) both terms are positive for all $p \geq p^\circ$: firm j has a real incentive to under-report the marginal clean-up cost function. However, it can be seen that when p falls below p°, the second term on the right-hand side of (5) becomes negative, and the overall pollution control policy cost function for firm j reaches a minimum for $p = p^* < p^\circ$ such that

$$\frac{dt(p^*)}{dp}\cdot x_j(t(p^*),p^*)$$

$$= \left[C^j_x\big(x_j(t(p^*),p^*);p^\circ\big) - C^j_x\big(x_j(t(p^*),p^*);p^*\big)\right]\cdot\frac{dx_j(t(p^*),p^*)}{dp}. \tag{9}$$

In contrast to statements taken for granted in current literature, if the Regulator requires each firm to pay the charge on the basis of the reported marginal clean-up cost function, then the incentive to under-report is no longer "unbounded": beyond a certain point, the savings on the emissions charge obtained by under-reporting become lower than the markedly increased clean-up cost required by the very low "consistent" pollution levels.

4. BOUNDS TO UNDER-REPORTING

Let us assume that firm j has avalaible all the information on the marginal aggregate clean-up cost function and the marginal expected social damage function possessed by the Regulator. It can then be asked: for what values of the relevant variables does the incentive to under-report approach zero? In other words, in what cases can p^* be expected to be only slightly lower than p°?

Substituting in (5) from (6) and from (7) and simplifying we obtain

$$D_{xx}\frac{C^j_{xx}}{C_{xx}} \gtreqless -\frac{C^j_x\left[x_j(t(p),p);p^\circ\right] - C^j_x\left[x_j(t(p),p);p\right]}{x_j(t(p),p)}. \tag{10}$$

Keeping in mind that $D_{xx} > 0$, $C_{xx} > 0$, and $C^j_{xx} > 0$, we can see that the left-hand side of (10) is positive for all p. The right-hand side of (10) becomes positive for $p < p^\circ$, because of what was seen earlier. We now observe that in the

[6] By differentiating condition (4) with respect to t and with respect to p and using (6), we have Eq. (7).

right-hand side of (10), the numerator gradually decreases and tends to zero as parameter p approaches p° from below. In the denominator, $x_j(t(p), p)$ increases and tends to $x_j(t(p^\circ), p^\circ)$, as p increases and tends to p° from below. Thus the right-hand side of (10) decreases and tends to zero as parameter p increases and tends to p° from below. Essentially, condition (10) is satisfied for values of parameter p that become closer and closer to p° the lower (i) D_{xx}, the slope of the marginal expected social damages function resulting from pollution,[7] and (ii) C^j_{xx}/C_{xx}, the relative slope of firm j's marginal clean-up cost function,[8] are.

On the one hand, if the marginal expected social damage function is only slightly increasing (expected social damage function approximately linear), then firms must expect that even a substantial under-reporting of the marginal clean-up cost function will achieve only a small reduction in the unit emissions charge in the Regulator's calculations. On the other hand, if the relative slope of the marginal clean-up cost function is fairly slight, the firm realizes that substantial under-reporting will lead to substantial reduction in the level of polluting waste discharge (since the firm is required to behave "consistently"). This translates into a remarkable increase in real total clean-up costs. Thus, while the firms achieve only slightly greater savings on the emissions charge with increasing under-reporting, clean-up costs show a marked increase: the advantage in under-reporting therefore proves to be rapidly decreasing (and tends to approach zero).

5. SUMMARY AND CONCLUSION

Two results have been presented:

(a) If the Regulator requires each firm to pay the charge based on the marginal clean-up cost function *reported*, thereby compelling firms to behave "consistently," then the incentive to under-report is no longer "unbounded." Firm j's overall pollution control policy cost function $F^j(p)$ is still decreasing with decreasing p for $p \geq p^\circ$, but it can reach a minimum for some $p < p^\circ$ and then begin to increase with further decreases in p. Thus the firm is no longer safe in under-reporting its clean-up cost function. The firm must acquire all information on the expected marginal social damage function resulting from pollution and on marginal clean-up cost functions reported by other firms in order to reconstruct the Regulator's calculations and, subsequently, solve the problem of minimizing the function $F^j(p)$. This is no mean undertaking!

[7] As a limit case, we can recall here a well-known result from the literature [1] according to which if the estimated function of expected social damage resulting from pollution is found to be linear (so that, at least in the relevant region, the expected marginal social damage function is constant; that is to say $D_{xx} = 0$), then the firm has no incentive to under-report the marginal clean-up cost function. Such a strategy would in any case not enable it to obtain a reduction in the charge t in the Regulator's calculations. In the case of "consistent" behavior considered in the text, if $D_{xx} = 0$ then condition (9) can be satisfied only for $p^* = p^\circ$. Thus, the overall cost function $F^j(p)$ would reach a minimum precisely with the true report.

[8] It can be seen that the relative slope of firm j's clean-up cost function decreases and tends to 1 under the following conditions: the lower the absolute slope of the function itself, the higher are the absolute slopes of the clean-up cost functions of other firms, and the greater are the number of firms involved.

(b) Moreover, if the marginal social damage cost function is found to be only slightly increasing and the marginal clean-up cost function only slightly decreasing with increasing polluting discharge levels, then any incentive the firm may have to under-report will be very limited (and close to zero). With decreasing p, firm j's overall cost function $F^j(p)$ reaches a minimum for a p only slightly below p°. In conclusion, whenever functions involved in this problem differ only slightly from linearity, the solution of using the information reported by firms to set the optimal emissions charge cannot be rejected a priori.

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