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ABSTRACT

The EPA's 2003 and 2008 National Pollution Discharge Elimination System for Confined Animal Feeding Operations (CAFOs) expanded the scope and stringency of the regulation of CAFOs but provided few if any additional enforcement resources. Enforcement of earlier regulations was poor, and the new regulations are likely to worsen this problem because they embody the usual approach of imposing one-size-fits-all rules. Because the likely damages from effluents vary greatly among CAFOs, depending on location, a system of emission fees that depend on likely damages would be more efficient. Alternatively, regulators could tailor enforcement efforts to probable damages. This paper provides a model that includes the total cost of regulation, including the government's monitoring and enforcement resources. Deploying fewer monitoring and enforcement resources on low-damage CAFOs and more on high-damage CAFOs can improve the efficiency of the regulatory regime, relative to equal enforcement of uniform regulations.

KEY WORDS Regulation; Optimal enforcement; CAFO

The EPA's 2003 and 2008 National Pollution Discharge Elimination System (NPDES) Regulations and Effluent Guidelines for Confined Animal Feeding Operations (CAFOs) increased the number of facilities that were regulated and tightened regulations of those that had previously been regulated. Though the scope and stringency of regulation were increased, relatively few resources were provided for enforcement of the new rules. A paper by Mullen and Centner (2004) has shown that increasing the number of firms regulated without increasing the

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enforcement budget may lead to a decrease in environmental quality, although this depends in part on the strategy of regulators. In fact, Mullen and Centner explore four strategies, some of which are at least ambiguous as to their effect on environmental quality.[1]

The EPA's regulations apply the same standards to all CAFOs. Nichols (1984) has pointed out that uniform standards for all firms are likely to be inefficient, both because different firms may have different costs of reducing emissions and because emissions from different firms cause different damages. We focus on the latter notion. CAFOs in different locations are likely to represent different risks of damage because they are in different proximity to bodies of water, are subject to different weather or soil conditions, are at varying distances from population centers, or because the bodies of water in the vicinity have different attractiveness for recreational benefits. (The great majority of the benefits that the EPA estimates will result from the new rules are in the form of recreational benefits. See USEPA 2002.)

There is a sizeable literature on selection of environmental instruments and on their application by regulators to achieve the optimal level of environmental quality at the lowest possible cost. One branch of this literature focuses on the idea of "targeting" policy to increase its effectiveness (for example, Harrington 1988; Helland 1998; Heyes 1999; Heyes 2002; Heyes and Sandeep 2009). According to Helland (1998), "Targeting is the practice of inspecting firms [that are] most likely to violate a regulation." The literature stems from a paper by Harrington (1988), which models the interaction between regulators and firms as a dynamic game. By more frequently inspecting firms that are more likely to be violators, regulators can induce firms to comply more fully with regulations.[2]

Our approach differs from that of the targeting literature in important ways. The targeting literature (e.g., Harrington 1988:35) looks at the problem from the standpoint of firm choice, within the context of a regulatory objective to maximize compliance with the mandated standards, given the level of fines and the probability of being audited. In our model, the objective is minimizing societal damage costs. Thus (following Mullen and Centner 2004), the main issue is the enforcement choice made by the regulators as a means to limit those costs. In the process, we describe a fully efficient system and indicate how the actual system must inevitably differ. Most importantly, we also focus on the fact that even given the same cost of control, the amount of damage caused by polluting firms will differ among sources and the socially efficient amount of control will therefore differ as well.

More specifically, we assume that because of these differences, the marginal reduction in damages resulting from increased effort at pollution control will differ among facilities. As a result, efficiency requires that regulators call for different CAFOs (each with the same incremental cost of effort) to engage in different levels of effort. We call this regulatory "tailoring." In principle, this outcome could be achieved by varying the emissions fees or fines imposed on CAFOs, reflecting the differences in the marginal damages that their emissions would cause. Alternatively, one could imagine a regime that specified individualized standards for different CAFOs, although this would add substantially to the cost of regulation. The EPA, however, has promulgated uniform, command-and-control type standards for all CAFOs.[3] Within that context, and given the limited resources of regulators, how can efficiency be achieved?

We begin with the model developed by Mullen and Centner (2004). A major element of that model is the notion that enforcement of regulations (by inspection and sanctions) is costly for the regulatory authority. The greater the inspection and enforcement budget of the regulatory authority, the greater the expected cost to the CAFO of its emissions and the greater the effort the

CAFO will undertake to reduce emissions. Our adaptation examines the effects of differential enforcement across the population of CAFOs due to locational factors alone. If emissions from some CAFOs are more damaging than emissions from other CAFOs, a policy of deploying more enforcement resources toward those whose emissions cause greater damage can improve efficiency.

In the next section of the article, we take a brief look at the history of the EPA's CAFO regulation. Then we develop a model for welfare gains through a differential-enforcement strategy. Discussion and a brief conclusion follow.

CAFO REGULATION

A CAFO is an animal-feeding operation containing a large number of animals (e.g., 10,000 hogs or 1000 cattle). The major environmental challenge that CAFOs present is the disposal of animal waste. Regulation focuses on two major components of the waste: nutrients (nitrogen, phosphorus, and potassium) and pathogens (bacteria and viruses). Because of the large number of animals involved (it may be in the thousands at an individual facility), managing waste from a CAFO is more complex than with traditional animal-feeding operations.

CAFOs contain the waste in holding tanks and spread it from time to time on cropland as fertilizer. Nutrients and pathogens can reach waterways because of a mechanical failure in the containment system, because excessive rainfall causes the containment system to overflow, or because the waste material is washed away from fields on which it has been deposited.

The regulations prior to 2003 covered most CAFO facilities for beef cattle, dairy cows, swine, turkeys, horses, and ducks, along with some layer hens and broiler chickens. The 2003 regulations covered many more broiler and layer operations for the first time. The new rules increased the number of regulated operations from approximately 12,500 to approximately 15,200. In addition, the 2003 and 2008 regulations are more stringent, requiring that CAFOs establish and employ "best management practice no discharge effluent limitations" for their facilities (see USEPA 2008b). There are at least two major problems with the new CAFO regulations. First, as noted by Mullen and Centner (2004), the enforcement of CAFO regulations has been poor. For example, they note that only about 20 percent of operations subject to the prior regulations obtained permits in a timely manner. With the increase in the number of regulated facilities, oversight is expected to deteriorate.[4] The optimal regulatory environment would probably entail a bigger inspection and enforcement budget than is now in place. If such a budget is not forthcoming, however, efficient use of the existing budget—by employing differential (that is, tailored) enforcement—could improve welfare.

MODEL

We assume that the regulatory agency wishes to minimize total costs and chooses among alternative regulatory processes, given its constraints with respect to monitoring and enforcement. We develop a model below that explores potential gains from a "tailored" monitoring and enforcement policy versus a uniform policy.

We assume that regulators face an industry of n firms who minimize regulatory costs according to the model in Mullen and Centner (2004). They model the decision of the regulated firm with respect to the amount of the firm's pollution-control effort (x). Firms are assumed to minimize C(x) + Expected Sanction (ES), where:

$$ES = P^{c,s}(x, xs, n, M, B)\cdot F \quad (1)$$

$P^{c,s}$ is the probability of being caught and sanctioned for being out of compliance; xs represents the amount of effort that would be required if the firm were to adhere completely to the standard; n is the number of firms regulated; M is the monitoring budget; B is the enforcement budget; and F is the fine or other sanction that is assessed if the firm is found to be in violation of the standard (Mullen and Centner 2004:211).

Mullen and Centner (2004) applied their model to the effects of increasing the scope of regulation (by increasing n, the number of firms regulated), as occurred under the 2003 revision of the CAFO rules. They show that the amount of effort expended per firm decreases if n increases while M and B are held constant. Consequently, the level of environmental quality provided by the regulatory regime might have increased or decreased as a result of the 2003 changes.

Mullen and Centner (2004) assume that all firms are required by the authorities to have the same level of effort; that is, that xs is constant across all firms. This is appropriate if one wants to model current EPA policy, but uniform standards are not optimal, for two reasons. First, as is well known, uniform standards fail to take account of differences across sources in the cost of control. Second, less often emphasized, such standards fail to take account of differences in marginal damages caused by emissions from different sources (Nichols 1984:83).

We consider the second of these issues. We assume that the regulatory agency faces the issue that marginal damage (D_x) caused by emissions is different for different firms. Thus, fully efficient regulation would minimize the expression

$$TC = \sum_{i=1}^{N} C^i\ (x_i) + \sum_{i=1}^{N} D^i\ (x_i) + M + B \quad (2)$$

Note that x_i is a function of M and B[5] (monitoring and enforcement) and that the partial derivatives of x_i with respect to monitoring and enforcement are positive.

If information about costs of control effort and damages from emissions were costless, M and B would be zero and the first-order condition for minimizing TC would be marginal cost = reduction in marginal damages (or $C^i_x = -D^i_x$). In other words, each firm should adjust its effort so that the reduction in damages resulting from a one-unit increase in effort equals the marginal cost of the increased effort. (The cost of reducing marginal damages is assumed to be the same for each firm.) If again information were costless, and thus regulators knew precisely the amount of damages each firm would cause, the regulatory agency could utilize efficient command-and-control regulation because each firm would be ordered to undertake the precise amount of effort so that $C^i_x = -D^i_x$.

Suppose enforcement is costly but the agency (1) has complete information on the amount of pollution that firms emit and the cost of the damages caused by the pollution; (2) has entirely flexible monitoring and enforcement budgets; and (3) knows that the socially efficient level of resources is available. Then the regulatory agency could still achieve optimality, even though one-size-fits-all command-and-control policies were being employed. Marginal expenditures on monitoring and enforcement would, in that case, be adjusted so that the net marginal gains from regulation equaled marginal costs; in other words, reduced damages minus the cost of added compliance would equal zero.

Further, if the regulatory agency had a socially efficient amount of resources but only probabilistic information about which firms would pollute and the costs of the damages they would cause, it might at least approach optimality. As noted above in equation (2), in such a setting, optimal regulation would minimize the sum of $C(x) + E(D(x)) + M + B$. An efficient regulatory agency would assign a different amount of effort (again assuming command-and-control regulation) to each firm depending on the firm's expected marginal damages and would set each firm's probability of being caught and sanctioned at a level such that the reduction in the firm's expected sanction (*ES*) resulting from a one-unit increase in *x* would approximately equal each firm's cost of damage reduction. Thus,

$$[E(D_x) + C_x] \cdot \frac{\partial x}{\partial M} + 1 = 0 \tag{3}$$

at the optimal level of enforcement.

But now suppose, as is the more realistic case, that regulators have imperfect information (i.e., only knowledge of probabilities of pollution costs of damage caused by different firms) and operate within fixed and limited budgets. In this case, we assume that firms are subject to the same standard of effort (*xs*), *M* and *B* are fixed by statute, and *n* has been increased by statute. (This is the situation following implementation of the 2003 and 2008 CAFO revisions.) It is unlikely that the outcome in this case will be fully optimal, but the regulatory authority can do better than simply confronting every firm with the same probability of audit. That is, there may be a lower amount of environmental damage if the regulatory authority tailors its monitoring and enforcement efforts differently to different subsets of the entire universe of firms subsumed by CAFO regulations. In this case, as we noted earlier, we divide firms into two groups: those that will do more and those that will do less environmental damage if they are out of compliance with the standard. Our contention is that the agency will reduce damages and thus social costs overall if it focuses more effort on firms that will do more damage than it does on those that will do less damage.

Remember that the firm's choice is to pick x^*, the amount of effort that minimizes *C(x) + Expected Sanction(x)*. If the regulatory authority wants to minimize (2) above, given its budgets and given that *xs* must be the same for each firm, it can do so by signaling that it is allocating its budget to make an audit more likely for some firms than for others.

Illustration with Two Types of Firms

Assume, then, for simplicity, that there are two types of firms, those with a high (absolute value of) D_x of emissions and those with a low (absolute value of) D_x of emissions. For the high-D_x firms, an increase in *x* would reduce expected damages more than it would for low-D_x firms. As noted above, if the authority had access to the socially efficient level of *M* and *B* (given that each firm's *xs* is the same), optimal policy would be to set audit probabilities at the level where:

$$[-D_x^{high} - C_x^{high}] \cdot \frac{\partial x}{\partial M} = [-D_x^{low} - C_x^{low}] \cdot \frac{\partial x}{\partial M} = 1 \tag{4}$$

or

$$[-D_x^{high} - C_x^{high}]\cdot\frac{\partial x}{\partial B} = [-D_x^{low} - C_x^{low}]\cdot\frac{\partial x}{\partial B} = 1$$

That is, at the optimal allocation of effort, increasing *M* or *B* by $1 provides a marginal net social benefit (the excess of the reduction in pollution damages over and above the extra control cost incurred by firms) of $1, whether the extra dollar of agency spending is targeted at high- or low-damage firms. Thus we have efficiency even without complete information.

The optimal case (when enforcement costs are included in the calculation) is shown in Figure 1. Each firm is nominally assigned a level of effort equal to *xs* (not shown). High- and low-damage firms face the same level of contingent sanction but different probabilities of being detected and sanctioned. The marginal benefit (reduction in expected sanction) due to a one-unit increase in effort *(x)* is higher for the high-damage firm than for the low-damage firm. If the regulatory authority sets the probabilities correctly (and it is assumed that, by virtue of its command of efficient social resources, it at least approximates the correct probabilities), the amount of effort by each type of firm will meet the condition specified above. The efforts that result generate a net social benefit of areas $a + b + c - d$, compared to the outcome in which all firms face equal probability of an audit despite the likelihood that some firms will cause more damage than others. The sum of pollution damages and firms' control costs will be lower than if the standard is applied uniformly.[6]

The key point for this approach is that even in the case in which the regulatory authority has less than the optimally sized *M* and *B* budgets (in fact, even when they are fixed well below the optimal, as is likely to be the case), it can reduce the sum of damage and firm effort costs (subject to the authority's budget constraint) by allocating its budget so that

$$\left[-D_x^{high} - C_x^{high}\right]\cdot\frac{\partial x}{\partial M} = [-D_x^{low} - C_x^{low}]\cdot\frac{\partial x}{\partial M} > 1 \quad (5)$$

or

$$[-D_x^{high} - C_x^{high}]]\cdot\frac{\partial x}{\partial B} = [-D_x^{low} - C_x^{low}]\cdot\frac{\partial x}{\partial B} > 1$$

That is, there are still gains to be made if the regulatory authority tailors its audit process so that the high-damage firms face a greater probability of audit, thus raising their *ES* costs. As firms are assumed to be minimizing the sum of their control costs and expected sanction costs, the cost of compliance now falls relative to the expected value of sanctions for high-damage firms, and they will engage in more control effort.

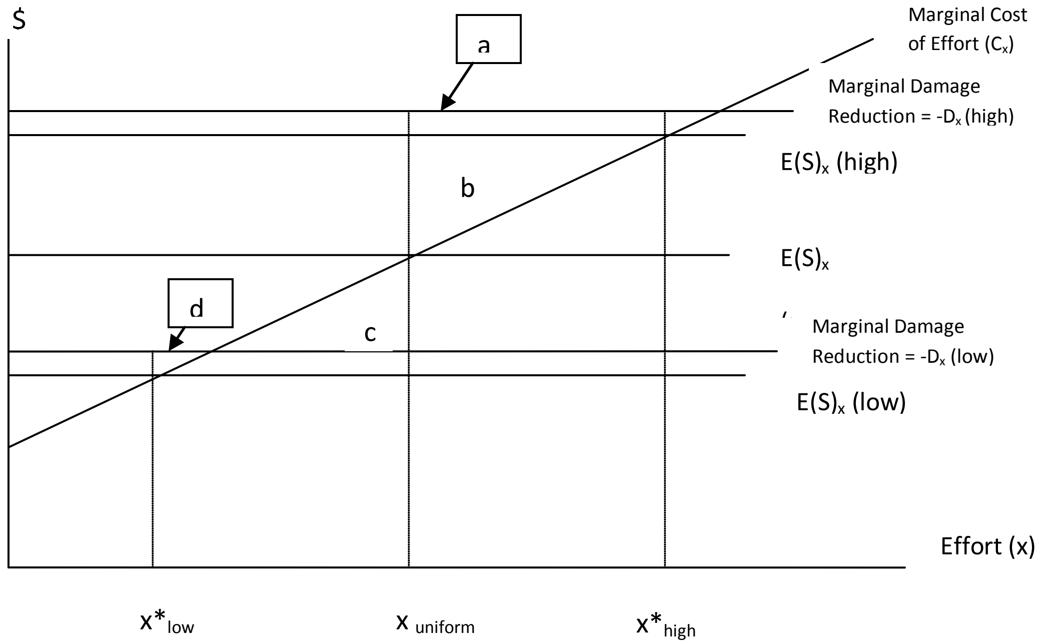

Figure 1. By "Tailoring" the Enforcement Effort to the Expected Marginal Damage, the Authority Can Generate Net Benefits of *a* + *b* + *c* – *d*, as Compared to the Outcome When Enforcement Effort Is the Same for All Firms

This is shown in Figure 2. Here, although the amount of the regulatory budget (*M* and *B*) is less than optimal, the allocation of resources (given monitoring and enforcement budget constraints) can nevertheless meet the condition specified in (5). (Also, it must be assumed that the size of the contingent sanction cannot be increased.) Note on the figures that there is now a larger gap between the marginal ES and the marginal reduction in damages because information about damages is imperfect and monitoring cannot be increased beyond the limits of the budget. Nonetheless, by dividing the firms into two groups (high and low) and tailoring the enforcement process to focus more heavily on the first group, there are clear social gains over a uniform approach. Again, an appropriate allocation of effort generates a net social benefit of areas $a + b + c - d$, compared to the equal-enforcement outcome; however, because monitoring and enforcement budgets are fixed below the socially optimal level and information is costly, the gain is not as great as it was in Figure 1. There are clear gains in social welfare, however, because the sum of pollution damage and firms' control costs is reduced compared to the case where the standard would be uniformly applied.

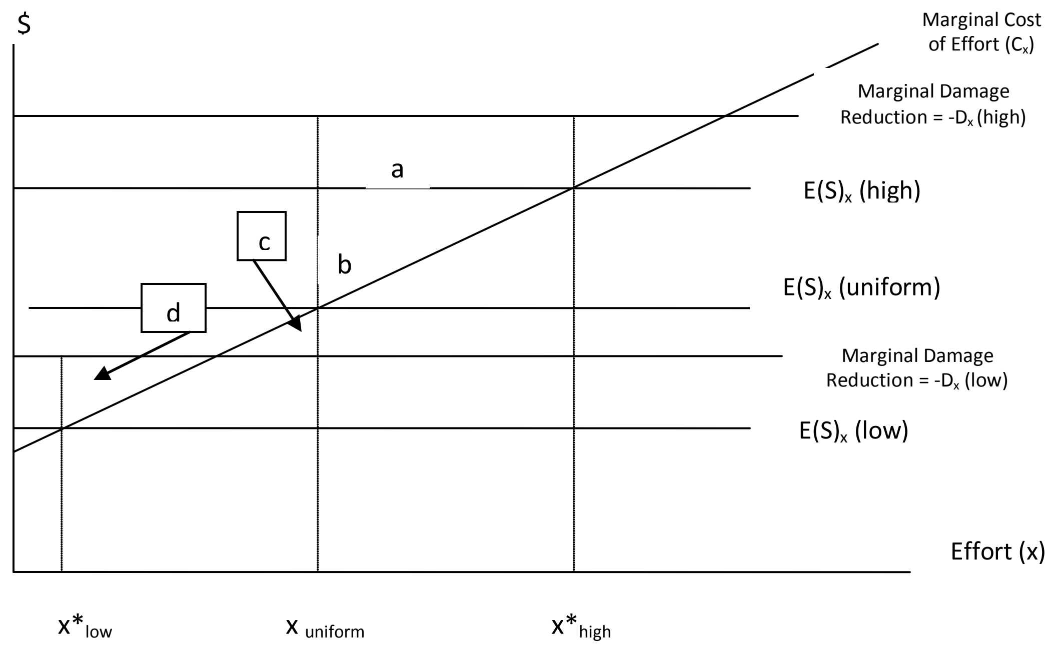

Figure 2. The Authority Does Not Have Sufficient Funds to Bring about Fully Optimal Control, but by Tailoring the Enforcement Effort to the Expected Marginal Damage, the Authority Can Generate Net Benefits of *a* + *b* + *c* – *d*, as Compared to the Outcome When Enforcement Effort Is the Same for All Firms

DISCUSSION AND CONCLUSION

The issue of targeting environmental rules has faced some criticism (see the discussion in Helland 1998), some of which may be applied to the tailoring model here. One argument is based on public-choice models that question how targeting might evolve in practice. Most important, if regulators can divide firms into groups more or less likely to be audited, then how can we be sure that their choices will be made on the basis of scientifically derived probable damages and not on the basis of interest-group influence? Indeed, Helland's empirical research on targeting (1998) suggests that interest groups do play a part in limiting the effectiveness of targeting with regard to the Clean Water Act. [See Huang and Miller (2006) for evidence that letting citizen complaints trigger inspections can be efficient.]

Still, the implications of the model we have presented are suggestive of the potential benefits of a "tailored" strategy for the design and implementation of CAFO policy. The model indicates gains that are likely even where the agency has limited funds and limited knowledge of firms—at least over an alternative of uniform monitoring and enforcement.[7] This would be most likely to be true when the judgments are to be made on a locational basis where there are likely to be competing interest groups and widely disseminated public information about local water, soil, and air quality.

It should be noted that this proposal would not imply that low-damage firms will never face an audit, only that the probability of an audit and thus the expected costs of noncompliance are low but still non-zero. Such firms would also be liable for damage, but because the damage from noncompliance would be relatively low, the benefit of raising the audit probability (that is, the expected cost to the CAFO) would be similarly low.

It would seem that this strategy might also apply in other instances of environmental regulation. Given differential damage costs, it is likely to be better for regulatory agencies with fixed (and limited) resources to tailor environmental audits to reflect those differences. Of course, it is necessary that differences in damage costs be measurable and that the source of the pollution be identifiable. Thus, regulators would be less likely to utilize this strategy with respect to, say, mobile air-pollution sources (cars and trucks) than they would with firms that fall under CAFO regulations. Still, the gains in this area alone would appear to be substantial even when imperfectly applied.

ENDNOTES

1. In response to a lawsuit (Waterkeeper Alliance *et al.* v. EPA), the 2003 NPDES rules were modified, but the basic rules remain in place. See Parry (2007) and USEPA (2008a).
2. One of the puzzles that the targeting literature attempts to explain is that compliance is often quite high, despite the fact that inspections are rare and fines for violations are low. The dynamic game formulation (Harrington 1988) helps explain these facts. This paper does not utilize the dynamic game methodology. Instead, following Mullen and Centner (2004), we assume that the CAFO owners rationally choose the amount of pollution-control effort by comparing the marginal cost of additional effort with the marginal benefit (in the form of reduced likelihood of sanctions) in a one-period decision model. And we assume that this also assumed by regulators. The contingent sanction, if the CAFO is found to be in violation, is assumed to be sufficiently high to induce the firm to engage in a certain level of effort. If the probability of inspection is reduced (given the level of sanction if the CAFO is found to be in violation), the amount of pollution-control effort will be reduced.
3. See USEPA (2002), pp. 1–10. The "effluent limitation guideline" (ELG) prohibits the "discharge of manure and other process wastewater from the production area, except when rainfall causes an overflow from a facility designed, constructed, operated, and maintained to contain all process wastewater and runoff from a 25-year, 24-hour (or more severe) rainfall event. The ELG also establishes certain best management practices (BMPs) that apply to the production area."
4. See Mullen and Centner (2004), p. 211. Specifically, the probability of being fined for a violation is decreasing and convex in n (the number of firms being regulated).
5. See Cole and Grossman (2002) for an extended discussion of the importance of including administrative costs (such as M and B in this paper) in the determination of optimal environmental control policy.
6. Recall that optimal policy minimizes the sum of damages, firms' control costs, M and B, but M and B are assumed to be held constant at their optimal levels.
7. It is possible that implementing the system we propose could entail some up-front costs of determining whether a given CAFO's emissions would result in high or low damages. For the regulatory regime we are proposing to be more efficient than standard one-size-fits-all regulation, the present discounted value of the net benefits enumerated in Figures 1 and 2

($a + b + c - d$) must exceed these up-front costs. We are grateful to the anonymous referee for pointing this out.

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