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## Environmental Citizen Suits with Pigovian Punitive Damages

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# Environmental Citizen Suits with Pigovian Punitive Damages

Sung-Hoon Park and Jason F. Shogren

## Abstract

Federal environmental laws encourage private citizens to act like "private attorney generals" and to sue a firm. This citizen group competes over the rewards of levels of regulation and enforcement. The firm can reduce its output to curtail the likelihood of losing the contest. This paper explores whether one can combine citizen suits with Pigovian punitive damages to equate private and social incentives. We show: (i) without punitive damages, the level of output of the firm is only optimal in a special case; (ii) with punitive damages given to the citizen group, Pigovian punitive damages can be found, but it could be negative—the citizen group might have to compensate the firm; (iii) the ideal level of punitive damages can be achieved if a government takes it; and (iv) punitive damages which are taken by the citizen group induces more effort expended in the conflict relative to when the government receives the punitive damages.

**KEYWORDS:** citizen suits, environmental damage, marginal environmental damage, marginal net benefit, Pigovian punitive damages, total legal expenditures

## 1. Introduction

In the United States, regulators promote the use of citizen suits to help enforce federal and state environmental laws (see Naysnerski and Teitenberg, 1992; Settle et al. 2003). Regular citizens are encouraged to act like “private attorney generals,” seeking out polluters and then suing them for damages in an environmental conflict. Citizen suits are said to be a deterrent for potential polluters. The threat of a suit could cause the polluter to account for the damages before the suit.

The existing literature exploring the nature of such conflicts has focused on the social costs of expending scarce resources fighting over a prize (e.g., Baik and Shogren, 1994; Liston-Heys, 2001). The open questions are whether the existence of the citizen suit provision alone is enough to induce the firm to select the socially efficient level of output, or whether the regulator should introduce an additional penalty provision, namely punitive damages. Punitive damages are frequently used to balance concerns for economic efficiency, retribution, and other rationales (see Luban and Eisenberg, 1998; Diamond, 2002). Now a victorious citizen group would receive payments in terms of damages suffered plus any punitive damages deemed warranted by the court.

Herein we develop an environmental conflict model to consider whether a regulator can use citizen suits with punitive damages to create a Pigovian instrument that could equate private and social incentives. We consider two-player (a firm and a citizen group) contests with citizen suits as punitive damages. The players are risk-neutral, and have equal legal ability. Events occur as follows. In the first stage, the firm maximizes its payoff by choosing what output to produce. The firm then announces its production plan to the public. In the second stage, after both parties know the projected output, the citizen group and the firm compete simultaneously and independently by irreversible effort level to win their prizes in the second stage. Using subgame-perfection as the solution concept, our results suggest that (i) without punitive damages, the level of output of the firm is only optimal in a special case; (ii) with punitive damages given to the citizen group, Pigovian punitive damages can be found, but it could be negative—the citizen group might have to compensate the firm; (iii) the ideal level of punitive damages can be achieved if a government takes it; and (iv) punitive damages which is taken by the citizen group induces more effort expended in the conflict relative to when the government receives the punitive damages.

In next section, we set up the two-stage game without punitive damages. In Section 3, we consider punitive damages for the citizen group. Section 4 presents the actual situation that exists in federal U.S. environmental law—the

government takes punitive damages if the citizen group wins the suit. Finally, we offer our concluding remarks in Section 5.

## 2. Citizen Suit without Punitive Damages

We first establish a benchmark model—a two-stage citizen suit game without punitive damages. Consider an environmental contest in which a firm and a citizen group expend effort competing with another to win their prize or rent. The firm expends observable and irreversible effort  $x$  to win profit  $G(Q)$ , which is a function of its output  $Q$ . Output, however, causes external environmental damage,  $D(Q)$ . The citizen group expends effort  $y$  to avoid the damages associated with output. Following contest theory, the probability the firm wins is  $p_x(x, y)$ , for  $x + y > 0$ , and  $p_x = 1/2$ , for  $x + y = 0$ ; where  $\partial p_x / \partial x > 0$  and  $\partial p_x / \partial y < 0$ , and  $\partial^2 p_x / \partial x^2 < 0$  and  $\partial^2 p_x / \partial y^2 > 0$ . Assume the players have the same legal ability in the contest, i.e.,  $p_x(x, y) = 1 - p_y(x, y)$ . Assume all information is common knowledge.

We now solve for the subgame perfect equilibrium of the benchmark contest. Consider first the second stage. Let  $L$  represent the expected loss for the citizen group. The citizens choose their effort  $y$  to minimize expected environmental damage  $D$  plus the legal expenditures:

$$\begin{aligned} \min (y) \quad & L = p_x D(Q) + y \\ \text{s.t.} \quad & y \geq 0, \end{aligned} \tag{1}$$

and the firm selects effort  $x$  to maximize its expected payoff independently:

$$\begin{aligned} \max (x) \quad & \pi = p_x G(Q) - x \\ \text{s.t.} \quad & x \geq 0, \end{aligned} \tag{2}$$

yielding the first-order conditions:<sup>1</sup>

$$(\partial p_x / \partial y) D(Q) + 1 = 0, \tag{3}$$

$$(\partial p_x / \partial x) G(Q) - 1 = 0. \tag{4}$$

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<sup>1</sup> The second-order conditions are satisfied in both cases with  $\partial^2 p_x / \partial x^2 < 0$  and  $\partial^2 p_x / \partial y^2 > 0$ .

We obtain a unique Nash equilibrium of this second-stage *subgame*,  $x = x(G(Q), D(Q))$  and  $y = y(G(Q), D(Q))$ , the probability-of-winning for the firm,  $p_x = p_x(G(Q), D(Q))$ , and the firm's indirect expected payoff,  $\pi = \pi(G(Q), D(Q))$ .<sup>2</sup> In the equilibrium of this second-stage subgame, we obtain a result which says the effect on the firm does not consider environmental damage.

**Proposition 1.** *Suppose the firm does not consider the environmental damage. (a) The firm increases its legal expenditures if and only if it is the contest favorite, i.e., has a greater than 50 percent chance of winning at the Nash equilibrium. (b) The citizen group increases its legal expenditures regardless of whether the group is the favorite or not.*

**Proof.** See Appendix A.

Now because the citizen suit exists, the firm accounts for the external damages in its indirect payoff function. The question is whether the existence of a citizen suit triggers partial or full internalization of the external damages by the firm.

We now work backwards and consider the first stage—the firm maximizes its expected payoff  $\pi(G(Q), D(Q))$  with respect to the output  $Q$  by solving:

$$\begin{aligned} & \operatorname{argmax} (Q) \pi(G(Q), D(Q)) \\ & \text{s.t. } Q \geq 0. \end{aligned} \tag{5}$$

The first- and second-order conditions are:

$$\frac{\partial \pi}{\partial G} \frac{\partial G}{\partial Q} + \frac{\partial \pi}{\partial D} \frac{\partial D}{\partial Q} = 0, \tag{6}$$

and

$$\frac{\partial^2 \pi}{\partial G^2} \left( \frac{\partial G}{\partial Q} \right)^2 + \frac{\partial \pi}{\partial G} \frac{\partial^2 G}{\partial Q^2} + \frac{\partial^2 \pi}{\partial D^2} \left( \frac{\partial D}{\partial Q} \right)^2 + \frac{\partial \pi}{\partial D} \frac{\partial^2 D}{\partial Q^2} < 0. \tag{7}$$

<sup>2</sup> Assume  $\partial x/\partial G > 0$ ,  $\partial x/\partial D (\geq \text{ or } \leq) 0$ ,  $\partial y/\partial G (\geq \text{ or } \leq) 0$ ,  $\partial y/\partial D > 0$ ,  $\partial p_x/\partial G > 0$ ,  $\partial p_x/\partial D < 0$ , and  $\partial \pi/\partial G > 0$ , and  $\partial \pi/\partial D < 0$ .

The term  $\partial G/\partial Q$  in expression (6) is marginal net benefit,  $MB (= MR - MC)$ ;  $\partial D/\partial Q$  is marginal environmental damage,  $MD$ . Expression (7) says that the sufficient condition to be satisfied with the second-order condition is  $\partial^2 \pi/\partial D^2 < 0$ . Expression (6) can be rewritten as:

$$MB = -\left\{\left(\frac{\partial \pi}{\partial D}\right)/\left(\frac{\partial \pi}{\partial G}\right)\right\}MD. \quad (8)$$

Expression (8) shows the relationship between marginal net benefit and marginal environmental damage. Without the citizen suit in the second stage, the firm would select its output such that marginal net benefit is zero,  $MB = MR - MC = 0$ . With the citizen suit, however, the firm now considers both marginal net benefit and a weighted fraction of the marginal damage,  $-\{(\partial \pi/\partial D)/(\partial \pi/\partial G)\}MD > 0$ . Now increasing output has two effects—a direct profit effect that increases the firm's payoff, and a weighted indirect citizen suit effect that decrease its payoff since greater damages trigger more effort by the citizen group. The weighting term captures at the margin the expected odds of victory in the contest given relative damages and profits, i.e., the marginal loss in payoffs due to litigated damages relative to the marginal gains in payoffs due to direct profits.

In general, the weighted indirect citizen-suit effect causes the firm to reduce output (i.e.,  $Q < Q^{**}$ ,  $MB > 0$ ). But we achieve the socially optimal level of output ( $Q = Q^*$ ) if and only if the weighting term equals unity,  $-\{(\partial \pi/\partial D)/(\partial \pi/\partial G)\} \equiv \theta = 1$ . If the weighting term is less than unity ( $\theta < 1$ ), the firm reduces output but it still overproduces relative to the social optimum,  $Q^* < Q < Q^{**}$ . If the opposite holds ( $\theta > 1$ ), the firm actually underproduces relative to the social optimum,  $Q < Q^*$ . The firm reduces its output as long as its expected payoff is positive. Proposition 2 summarizes the choice of output in the first stage.

**Proposition 2.** *Assuming the firm's payoff is concave in its output, the existence of a citizen-suit mechanism (a) causes the firm to reduce its output, because now it internalizes how its output affects the citizen group, and therefore reduces its likelihood of losing the suit. (b) The magnitude of the reduction in output, however, depends on the relative magnitude of the marginal indirect damage effects  $-(\partial \pi/\partial D)$  and marginal direct profit effect,  $(\partial \pi/\partial G)$ . (c) A citizen suit induces a socially efficient level of output only in a special case of equal marginal direct-profit effects and marginal indirect-damage effects. (d) Otherwise, a firm overproduces (under-produces) output relative to the social optimum if the indirect-damage effect is small (large) relative to the direct-profit effect.*

We gain additional insight into our result by reframing the general model using the classic Logit contest success function used throughout the contest literature.<sup>3</sup> Now the probability of the firm winning is  $p_x = x/(x + y)$ , and the citizen group winning is  $p_y = (1 - x/(x + y))$ . Let the firm's profit function be  $G = P(Q)Q - C(Q)$ . In the second stage, the citizen group selects a level of contest effort  $y$  to minimize expected environmental damage  $D$  plus legal expenditures, and the firm maximizes its expected payoff simultaneously and independently (see expressions (1) and (2)). By doing so, we obtain reaction function for the firm and the citizen group. Solving the two reaction functions jointly, we obtain a unique Nash equilibrium in the second stage of this *subgame*.

**Lemma 1.** *At the Nash equilibrium in the second-stage of the subgame, the effort levels of the players are  $x^N = G^2D/(G + D)^2$  and  $y^N = GD^2/(G + D)^2$ , the firm's expected payoff is  $\pi^N = G^3/(G + D)^2$ , and the citizen group's expected loss is  $L^N = GD(G + 2D)/(G + D)^2$ .*

Lemma 1 says that environmental damage is (partially) internalized when the firm maximizes its payoff in the first stage. In the first stage, the firm chooses its output to maximize the expected payoff:

$$\begin{aligned} \arg \max(Q) \pi^N &= \frac{\{P(Q)Q - C(Q)\}^3}{\{P(Q)Q - C(Q) + D(Q)\}^2} \\ \text{s.t. } Q &\geq 0. \end{aligned} \tag{9}$$

The first-order condition for maximizing the firm's expected payoff  $\pi^N$  gives

$$MB = \{2G/(G + 3D)\}MD. \tag{10}$$

Examining expression (10), we see the Logit equivalent of expression (8), in which the weighting term takes the form  $-(\partial\pi/\partial D) = 2G$  and  $(\partial\pi/\partial G) = (G + 3D)$ , which we summarize in Corollary 1.

**Corollary 1.** *(a) If the firm's profit is three times environmental damage  $G = 3D$ , the citizen suit induces the firm to select the socially optimal level of output; (b) if  $G < 3D$ , which implies a relatively steep marginal damage curve, the citizen suit*

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<sup>3</sup> The Logit function is used extensively in the contest literature, see, for example Tullock (1980), Dixit (1987), Baik and Shogren (1994), Heyes (1997), Hurley and Shogren (1997), and Liston-Heyes (2001).

*induces the firm to reduce its output but it still overproduces relative to the social optimum,  $Q^* < Q < Q^{**}$ ; and (c) if  $G > 3D$ —which implies a relatively flat marginal damage curve, the firm underproduces output relative to the social optimum,  $Q < Q^*$ .*

### **3. Pigovian Punitive Damages for the Citizen Group**

With citizen suits but without punitive damages, the level of output of the firm is optimal only under specific conditions. We now explore whether adding punitive damage could be used to equate private and social incentives (see for example Diamond, 2002). Let  $PN$  denote the level of punitive damages paid to the citizen group selected by a regulator.

In the second stage, the citizen group chooses a level of contest effort  $y$  to minimize the expected loss:

$$\begin{aligned} \min (y) \quad & L = p_x(D + PN) - PN + y \\ \text{s.t.} \quad & y \geq 0, \end{aligned} \tag{11}$$

and the firm's problem is to maximize its expected payoff by

$$\begin{aligned} \max (x) \quad & \pi = p_x(G + PN) - PN - x \\ \text{s.t.} \quad & x \geq 0. \end{aligned} \tag{12}$$

The first-order conditions for minimizing and maximizing each player's expected loss  $L$  and payoff give:

$$(\partial p_x / \partial y)(D + PN) + 1 = 0, \tag{13}$$

$$(\partial p_x / \partial x)(G + PN) - 1 = 0. \tag{14}$$

This subgame has a unique Nash equilibrium in the second stage. We denote it by  $\{x(G(Q) + PN, D(Q) + PN), y(G(Q) + PN, D(Q) + PN)\}$ .

At the second stage, having perfect sight about expected payoff,  $\pi(G(Q) + PN, D(Q) + PN; PN)$ , the firm seeks to maximize its expected payoff choosing its output:

$$\begin{aligned} & \operatorname{argmax} (Q) \pi(G(Q) + PN, D(Q) + PN; PN) \\ & \text{s.t. } Q \geq 0. \end{aligned} \quad (15)$$

The first- and second-order conditions for maximizing the firm's expected payoff  $\pi$  give:

$$\frac{\partial \pi}{\partial(G + PN)} \frac{\partial G}{\partial Q} + \frac{\partial \pi}{\partial(D + PN)} \frac{\partial D}{\partial Q} = 0, \quad (16)$$

and

$$\frac{\partial^2 \pi}{\partial(G + PN)^2} \left( \frac{\partial G}{\partial Q} \right)^2 + \frac{\partial \pi}{\partial(G + PN)} \frac{\partial^2 G}{\partial Q^2} + \frac{\partial^2 \pi}{\partial(D + PN)^2} \left( \frac{\partial D}{\partial Q} \right)^2 + \frac{\partial \pi}{\partial(D + PN)} \frac{\partial^2 D}{\partial Q^2} < 0. \quad (17)$$

Expression (16) can be rewritten as:

$$MB = -\left\{ \left( \frac{\partial \pi}{\partial(D + PN)} \right) / \left( \frac{\partial \pi}{\partial(G + PN)} \right) \right\} MD. \quad (18)$$

Expression (18) shows the increase in output is affected by both  $\partial \pi / \partial(G + PN)$  and  $|\partial \pi / \partial(D + PN)|$ . The reason is that punitive damages have two properties: an opportunity cost in rents for the firm and an extra prize for the citizen group. Whether the regulator can use punitive damages to induce a firm to reduce its output to optimal levels depends on both the numerator and denominator in (18): even if the numerator is reduced, the denominator is also reduced.

**Proposition 3.** *The optimal punitive damages would set PN so  $\partial \pi / \partial(G + PN)$  equals  $|\partial \pi / \partial(D + PN)|$ , such that  $MB = MD$  in expression (18).*

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<sup>4</sup> The sufficient condition to satisfy the second-order condition is  $\partial^2 \pi / \partial(D + PN)^2 < 0$ .

Punitive damages as a Pigovian tool can be further understood using the Logit contest success function. Lemma 2 summarizes the unique Nash equilibrium in the second stage of this subgame.

**Lemma 2.** *At the Nash equilibrium in the second stage of the subgame, the effort levels of the players are  $x = (G + PN)^2(D + PN)/(G + D + 2PN)^2$  and  $y = (G + PN)(D + PN)^2/(G + D + 2PN)^2$ , the firm's expected payoff is  $\pi = (G + PN)^3/(G + D + 2PN)^2 - PN$ , and the citizen group's expected loss is  $L = \{(G + PN)(D + PN)(G + 2D + 3PN)\}/(G + D + 2PN)^2 - PN$ .*

At the first stage, the firm chooses its output to maximize expected payoff

$$\begin{aligned} \text{argmax } (Q) \quad \pi &= \frac{\{P(Q)Q - C(Q) + PN\}^3}{\{P(Q)Q - C(Q) + D(Q) + 2PN\}^2} - PN, \\ (19) \quad \text{s.t. } Q &\geq 0, \end{aligned}$$

yielding the expression

$$(20) \quad MB = \{2(G + PN)/(G + 3D + 4PN)\}MD.$$

We solve expression (20) for  $PN$  to get Corollary 2.

**Corollary 2.** *Suppose any punitive damages are distributed to the citizen group if they are victorious in the environmental conflict. The level of Pigovian punitive damages (when positive) is  $PN^{CG} = (G^* - 3D^*)/2$ . (a) If  $G^* > 3D^*$ , Pigovian punitive damages are positive; (b) if  $G^* < 3D^*$ , Pigovian punitive damages are negative.*

Corollary 2 illustrates the optimal level of punitive damages that would induce a firm to set its output level to socially efficient levels. Part (a) says that the punitive damages would be positive; part (b) of Corollary 2 suggests conditions exist when punitive damages could be negative (also see Diamond, 2002). With fewer environmental damages or greater profit, more punitive damages can be tolerated. Even if punitive damages  $PN^{CG}$  induce the firm to produce the socially optimal level of output, a negative  $PN^{CG}$  is unlikely to be applied in practice. Combining Corollaries 1 and 2, we obtain that exogenous Pigovian punitive damages taken by the citizen group may be a *mis-measurement* to set the firm's output level to socially efficient levels. The reason is as follows. If the firm

underproduces output relative to the social optimum (i.e.,  $Q < Q^*$ ), punitive damages taken by the citizen group could be negative. If the firm overproduces relative to the social optimum (i.e.,  $Q > Q^*$ ), punitive damages taken by the citizen group would be positive.

Given Corollary 2 and Lemma 2, Lemma 3 summarizes the patterns of Nash equilibrium effort levels, expected payoff, and expected loss.

**Lemma 3.** *Given punitive damages taken by the citizen group, the effort level of the players are  $x^{CG} = 9(G^* - D^*)/32$  and  $y^{CG} = 3(G^* - D^*)/32$ , the total legal expenditures are  $x^{CG} + y^{CG} = 3(G^* - D^*)/8$ , the firm's expected payoff is  $\pi^{CG} = (69D^* - 5G^*)/32$ , and the citizen group's expected loss is  $L^{CG} = (D^* - G^*)/32$ .<sup>5</sup>*

Lemma 3 says the effort levels are positive since  $G^* > D^*$ , even though the firm's expected payoff is likely to be negative.

Next consider the case in which punitive damages are endogenous in the level of environmental damages;  $PN(D)$ . Given expression (19), we obtain (21):

$$MB = \theta^{cg}(G, D, PN; \partial PN^{cg} / \partial D)MD. \quad (21)$$

Given  $MB = MD$  (i.e.,  $\theta^{cg} = 1$ ) and evaluated at  $PN = 0$ , expression (21) yields

$$(\partial PN^{cg} / \partial D) \Big|_{PN=0} = (G^*)^2(3D^* - G^*) / \{2(G^*)^3 + (D^*)^2(3G^* + D^*)\}. \quad (22)$$

The limitation of applying the endogenous variables as punitive damages is that the firm's expected payoff may not be concave in its output in the first stage—the sign of the second-order condition depends on  $\partial PN / \partial D$  and  $\partial^2 PN / \partial D^2$ . This implies that we may face multiple Nash Equilibria or we may not find any Nash equilibria in the subgame. Another limitation is conducted from expression (22). The expression shows that, with no punitive damages, the level of output of the firm is only optimal in a special case, i.e.,  $3D^* - G^* = 0$ .

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<sup>5</sup> Throughout, we use an \* to emphasize that the Nash equilibrium is from the optimal level of output of the firm.

#### 4. Pigovian Punitive Damages to the Government

Now consider the actual situation that exists in federal U.S. environmental law—the government takes punitive damages if the citizen group wins the suit. Consider the second stage of the game. The citizen group’s problem is to minimize the expected loss in expression (1), and the firm maximizes its expected payoff independently by

$$\begin{aligned} \max (x) \quad & \pi = p_x(G + PN) - PN - x \\ \text{s.t. } & x \geq 0. \end{aligned} \tag{23}$$

The first-order conditions are

$$(\partial p_x / \partial y)D + 1 = 0, \tag{24}$$

$$(\partial p_x / \partial x)(G + PN) - 1 = 0. \tag{25}$$

This subgame has a unique Nash equilibrium in the second stage, denoted by  $\{x(G(Q) + PN, D(Q)), y(G(Q) + PN, D(Q))\}$ .

At the second stage, having perfect sight about  $\pi(G(Q) + PN, D(Q); PN)$ , the firm chooses the level of output that maximizes its expected payoff:

$$\begin{aligned} \operatorname{argmax} (Q) \quad & \pi(G(Q) + PN, D(Q); PN) \\ \text{s.t. } & Q \geq 0. \end{aligned} \tag{26}$$

The first- and second-order conditions for maximizing the firm’s expected payoff give:

$$\frac{\partial \pi}{\partial (G + PN)} \left( \frac{\partial G}{\partial Q} \right) + \frac{\partial \pi}{\partial D} \frac{\partial D}{\partial Q} = 0, \tag{27}$$

and

$$(28) \quad \frac{\partial^2 \pi}{\partial(G + PN)^2} \left( \frac{\partial G}{\partial Q} \right)^2 + \frac{\partial \pi}{\partial(G + PN)} \left( \frac{\partial^2 G}{\partial Q^2} \right) + \frac{\partial^2 \pi}{\partial D^2} \left( \frac{\partial D}{\partial Q} \right)^2 + \frac{\partial \pi}{\partial D} \left( \frac{\partial^2 D}{\partial Q^2} \right) < 0.$$

Expression (27) can be rewritten as follows:

$$(29) \quad MB = -\left\{ \left( \frac{\partial \pi}{\partial D} \right) / \left( \frac{\partial \pi}{\partial(G + PN)} \right) \right\} MD.$$

Now compare expressions (8) and (29). Assume, without loss of generality, that marginal payoff meets two requirements: it is positive and decreasing. The requirements show  $\partial \pi / \partial G > \partial \pi / \partial(G + PN)$  for  $PN > 0$ , and  $\partial \pi / \partial G < \partial \pi / \partial(G + PN)$  for  $PN < 0$ . Recalling expression (8), the regulator selects the size of punitive damages such that the firm equates its private goals with the broader social incentives. Using expression (29), we state the following proposition.

**Proposition 4.** *If punitive damages are awarded to the regulator, an optimal level of Pigovian punitive damages can be found to induce a firm to reduce its output to socially efficient levels.*

Proposition 4 says punitive damages can work as a Pigovian tool—provided that the rewards accrue to the government, not to the citizen group.

Again considering the case of the Logit success function, in the second stage, the citizen group chooses a level of contest effort  $y$  to minimize the expected loss, and the firm maximizes its expected payoff independently.<sup>6</sup> This subgame has a unique Nash equilibrium in the second stage.

**Lemma 4.** *At the Nash equilibrium in the second stage of the subgame, the effort levels of the players are  $x = (G + PN)^2 D / (G + D + PN)^2$  and  $y = (G + PN) D^2 / (G + D + PN)^2$ , the firm's expected payoff is  $\pi = \{(G + PN)^3 / (G + D + PN)^2\} - PN$ , and the citizen group's expected loss is  $L = (G + PN)(G + 2D + PN) D / (G + D + PN)^2$ .*

At the first stage, the firm chooses output to maximize expected payoffs:

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<sup>6</sup> The second-order conditions are satisfied in both cases.

$$\begin{aligned} \text{argmax } (Q) \quad \pi^G &= \frac{\{P(Q)Q - C(Q) + PN\}^3}{\{P(Q)Q - C(Q) + D(Q) + PN\}^2} - PN \\ \text{s.t. } Q &\geq 0, \end{aligned} \tag{30}$$

which yields the condition:

$$MB = \{2(G + PN)/(G + 3D + PN)\}MD. \tag{31}$$

From expression (31), we obtain Corollary 4.

**Corollary 4.** *The ideal level of Pigovian punitive damages (when positive) is that  $PN^G = 3D^* - G^*$ . (a) If  $G^* < 3D^*$ , Pigovian punitive damages are positive; (b) if  $G^* > 3D^*$ , Pigovian punitive damages are negative.*

From Corollary 4, if firm profits are less than three times the damages,  $G^* < 3D^*$ , the regulator can impose a Pigovian punitive damages on the firm. But if the firm's profits are sufficiently greater than damage, the firm reduces its output such that  $Q < Q^*$ . Now again the regulator can only equate private and social incentives if it subsidizes the firm.

Given Corollary 4 and Lemma 4, Lemma 5 summarizes the patterns of Nash equilibrium effort levels, expected payoff, and expected loss.

**Lemma 5.** *At the Nash equilibrium in the second stage of the subgame, the effort levels of the players are  $x^G = 9D^*/16$  and  $y^G = 3D^*/16$ , the total legal expenditures are  $x^G + y^G = 3D^*/4$ , the firm's expected payoff is  $\pi^G = (16G^* - 21D^*)/16$ , and the citizen group's expected loss is  $L^G = 3(4 + D^*)/16$ .*

Lemma 5 says that the effort levels are positive, and the firm's outcome is usually positive. From Lemma 3 and Lemma 5, Proposition 5 characterizes the difference between two total legal expenditures.

**Proposition 5.** *If the regulator cannot impose negative punitive damages on the citizen group, total expenditures for punitive damages taken by the citizen group are always greater than total expenditures for punitive damages taken by the government.*

**Proof.** The proof of the case of  $G > 3D$  is straightforward and therefore omitted. With the case of  $G < 3D$  and  $PN^{CG} = 0$ , the total expenditures of the citizen group are  $GD/(G + D)$ , while the total expenditures of the firm are  $3D^*/4$ . Recalling Corollary 1, if  $G < 3D$ , the firm overproduces relative to the social optimum. This implies  $G^*D^*/(G^* + D^*) < GD/(G + D)$  since  $G^* < G$  and  $D^* < D$ . Next comparing  $G^*D^*/(G^* + D^*)$  with  $3D^*/4$ , we find that  $3D^*/4 < G^*D^*/(G^* + D^*)$ . Herein we obtain that  $3D^*/4 < GD/(G + D)$ .

Proposition 5 says that when the government cannot impose negative punitive damages on the citizen group, punitive damages which are taken by the citizen group incur greater total expenditures than punitive damages taken by the government.

Next consider punitive damages are endogenous in environmental damages;  $PN(D)$ . Given expression (30), we obtain expression (32):

$$MB = \theta^g(G, D, PN; \partial PN^g / \partial D)MD. \quad (32)$$

Given  $MB = MD$  (i.e.,  $\theta^g = 1$ ) and evaluated at  $PN = 0$ , expression (32) yields

$$(\partial PN^g / \partial D)\Big|_{PN=0} = \{(G^*)^2(3D^* - G^*) / (D^*)^2(3G^* + D^*)\}, \quad (33)$$

which induces the results to be same with expression (22): with no punitive damages, the level of output of the firm is only optimal in a special case, i.e.,  $3D^* - G^* = 0$ .

From expressions (22) and (33), we obtain Proposition 6.

**Proposition 6.** *Suppose that the punitive damages are endogenous. The punitive damages are of no use to equate private and social incentives.*

## 5. Concluding Remarks

Federal environmental laws in the United States encourage private citizens to act like “private attorney generals” by subsidizing their efforts to sue polluting firms. This paper develops an environmental-conflict model in which a firm and a citizen group choose the amounts of competition over the rewards of levels of regulation and enforcement. We have also explored whether one can use citizen suits with Pigovian punitive damages to equal private and social incentives.

Unlike other analyses that simply take rewards as a given, we have explicitly modeled the expenditure-reward relationship in which the firm's output is an endogenous variable.

Using a general probability-of-winning function and a specific logit function, we have examined the effect of increasing the firm's output. We have characterized the subgame-perfect equilibrium and examined whether one can use citizen suits with Pigovian punitive damages to equal private and social incentives. Our results suggest that: (i) without punitive damages, the level of output of the firm is only optimal in a special case; (ii) with punitive damages given to the citizen group, Pigovian punitive damages can be found, but this could be negative—the citizen group might have to compensate the firm; (iii) the ideal level of punitive damages can be achieved if a government takes the compensation for damages; (iv) punitive damages taken by the citizen group induce more effort expended in the conflict relative to when the government receives the punitive damages; and (v) endogenous punitive damages are of no use to equate private and social incentives.

## APPENDIX A

The effects on expenditure of small changes in the explanatory variables are found by differentiating the first-order conditions in expressions (3) and (4):

$$G(Q)(\partial^2 p_x / \partial x^2) dx + G(Q)(\partial^2 p_x / \partial x \partial y) dy + (\partial p_x / \partial x) MBdQ = 0, \quad (3a)$$

and

$$D(Q)(\partial^2 p_x / \partial y \partial x) dx + D(Q)(\partial^2 p_x / \partial y^2) dy + (\partial p_x / \partial y) MDdQ = 0. \quad (4a)$$

The contest literature suggests that the signs of the slopes of the reaction functions are critical determinants of players' strategic behavior in equilibria. Rearrangement of expressions (3a) and (4a) shows that the slope of the firm's reaction function is equal to  $dx/dy = -(\partial^2 p_x / \partial x \partial y) / (\partial^2 p_x / \partial x^2)$ , and that the slope of the citizen group's reaction function is equal to  $dy/dx = -(\partial^2 p_x / \partial y^2) / (\partial^2 p_x / \partial y \partial x)$ . Since  $\partial^2 p_x / \partial x^2 < 0$  and  $\partial^2 p_x / \partial y^2 > 0$ , the two slopes must be of opposite signs when they intersect. As Katz (1988) suggests, the sign of  $\partial^2 p_x / \partial y \partial x (= \partial^2 p_x / \partial x \partial y)$  implies that an increase in the effort level of the favorite player leads to a decrease in his opponent's effort level, and that an increase in the effort level of the underdog player leads to an increase in its opponent's effort level. With our

assumption that players have the same legal ability for the contest, the positive sign of  $\partial^2 p_x / \partial y \partial x$  means the firm is the favorite, and the negative sign of that means the firm is the underdog.

Which player between the firm and the citizen group is favored in equilibrium depends on the value of the exogenous parameter  $Q$  in our model. We now solve for reduced-form expression for the change in the exogenous variable  $x$  and  $y$ . Simultaneous solution of expressions (3a) and (4a) yields:

$$G \{ \partial^2 p_x / \partial x^2 - (\partial^2 p_x / \partial x \partial y)^2 / (\partial^2 p_x / \partial y^2) \} dx - \{ G \cdot MD(\partial^2 p_x / \partial x \partial y)(\partial p_x / \partial y) / D(\partial^2 p_x / \partial y^2) - MB(\partial p_x / \partial x) \} dQ = 0, \quad (3b)$$

and

$$D \{ -(\partial^2 p_x / \partial y^2) + (\partial^2 p_x / \partial x \partial y)^2 / (\partial^2 p_x / \partial x^2) \} dy - \{ D \cdot MB(\partial^2 p_x / \partial x \partial y)(\partial p_x / \partial x) / G(\partial^2 p_x / \partial x^2) - MD(\partial p_x / \partial y) \} dQ = 0. \quad (4b)$$

A change in the exogenous parameter  $Q$  will affect the players' legal expenditures directly by changing the marginal value of expenditures and also indirectly as each player considers marginal net benefit and marginal damage to the direct change. Expressions (3c) and (4c) show the effects:

$$dx/dQ = \frac{\{ G \cdot MD(\partial^2 p_x / \partial x \partial y)(\partial p_x / \partial y) / D(\partial^2 p_x / \partial y^2) - MB(\partial p_x / \partial x) \}}{\div G \{ \partial^2 p_x / \partial x^2 - (\partial^2 p_x / \partial x \partial y)^2 / (\partial^2 p_x / \partial y^2) \}}, \quad (3c)$$

and

$$dy/dQ = \frac{\{ MD(\partial p_x / \partial y) - D \cdot MB(\partial^2 p_x / \partial x \partial y)(\partial p_x / \partial x) / G(\partial^2 p_x / \partial x^2) \}}{\div D \{ (\partial^2 p_x / \partial x \partial y)^2 / (\partial^2 p_x / \partial x^2) - (\partial^2 p_x / \partial y^2) \}}, \quad (4c)$$

where the denominators of the notations at expressions (3c) and (4c) are negative while the numerators of these depend upon the firm's profit and environmental damage (which are the function of the firm's output), and probability-of-winning (which is the function of each player's legal expenditures).

We consider the signs of  $dx/dQ$  and  $dy/dQ$  when the firm's marginal net benefit is zero at  $Q^{**}$  in Figure 1. It follows from expression (3c) and (4c) that:

$$\frac{dx/dQ}{\overline{MD}(\partial^2 p_x/\partial x \partial y)(\partial p_x/\partial y) \div \overline{D}(\partial^2 p_x/\partial y^2)\{\partial^2 p_x/\partial x^2 - (\partial^2 p_x/\partial y \partial x)^2/(\partial^2 p_x/\partial y^2)\}}, \quad (3d)$$

and

$$\frac{dy/dQ}{\overline{MD}(\partial p_x/\partial y) \div \overline{D}\{(\partial^2 p_x/\partial x \partial y)^2/(\partial^2 p_x/\partial x^2) - (\partial^2 p_x/\partial y^2)\}} > 0, \quad (4d)$$

where the values of  $\overline{G}$ ,  $\overline{D}$ , and  $\overline{MD}$  at expression (3d) and (4d) imply the firm's profit, the environmental damage, and the marginal environmental damage when the firm seeks to maximize its profit at  $MB = 0$ . Some observations follow immediately. As we mentioned early, the denominators of the notations are negative at expressions (3d) and (4d). Thus,  $\text{sgn}[dx/dQ] = \text{sgn}[\partial^2 p_x/\partial x \partial y]$  at expression (3d): the firm increases its legal expenditures if and only if the notation of  $\partial^2 p_x/\partial x \partial y$  is positive. The sign of the numerator at expression (4d) is always negative.  $\square$

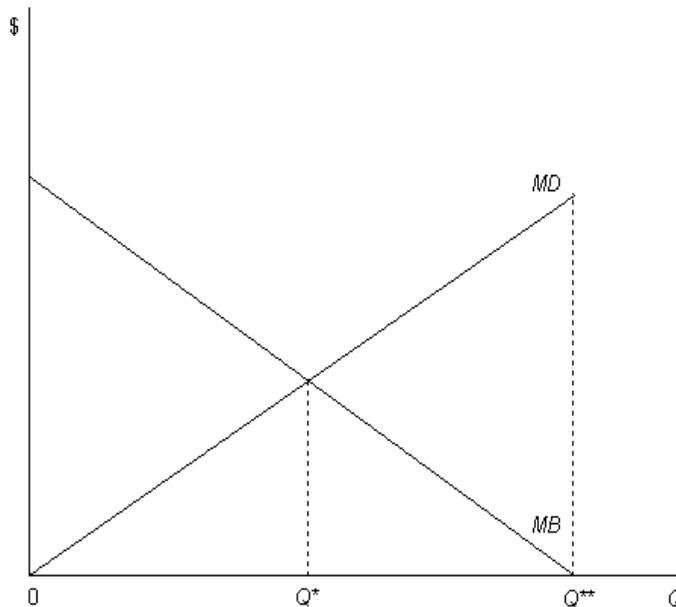


Figure 1: Equilibrium Output

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