COOPERATION, DETERRENCE, AND THE ECOLOGY OF REGULATORY ENFORCEMENT

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An ecological model based on evolutionary game theory is developed to analyze the role of egoistic cooperation in regulatory enforcement. The model demonstrates that socially beneficial cooperation depends on 1) a combination of cooperative and deterrence routines in an enforcement strategy that is at once vengeful and forgiving, 2) firms concerned enough about future enforcement encounters to forgo short-term gains from evasion, and 3) institutional arrangements that provide suitable sanctions and cost tradeoffs for existing enforcement and evasion technologies in the particular enforcement arena. Factors limiting the advantage of cooperation are also reviewed, and other applications of the model are suggested.

In many enforcement arenas, two distinctive enforcement strategies have commonly been observed and advocated by students of law and public policy. The deterrence or rule-oriented strategy seeks to coerce compliance through the maximal detection and sanctioning of violations of legal rules. Advocates of this strategy emphasize the need for mechanisms to ensure that amoral subjects find it in their best interest to comply with the law (Becker, 1968; Ehrlich, 1973; Stigler, 1970). The emphasis on rational decisions and cost calculations in this perspective has been particularly influential in the analysis of regulatory compliance (Diver, 1980; Downing and Kimball, 1982; Downing and Hanf, 1983; Peltzman, 1975; Smith, 1976; Viscusi, 1979; Viscusi and Zeckhauser, 1979), since this emphasis is also central to contemporary management theories and the economic theory of the firm. Recent reforms to increase deterrence in regulatory as well as criminal justice systems

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attest to the widespread belief in this simplified form of deterrence theory.

The cooperative strategy, on the other hand, emphasizes flexible or selective enforcement that takes into consideration the particular circumstances of an observed violation. Proponents of this strategy, which some analysts have called result-oriented (Nonet and Selznick, 1978), reasonable (Bardach and Kagan, 1982), professional (Muir, 1977), and judicial (Kagan, 1978), emphasize the difficulty of applying abstract rules to complex situations and argue that attempts to fully enforce legal rules are unlikely to achieve desired ends. Implicitly, at least, this perspective assumes a willingness to obey legitimate laws, and therefore stresses the need for reasonable enforcement and persuasion rather than coercion. Studies of regulatory agencies (Carson, 1970; Hawkins, 1984; Kelman, 1982; Bardach and Kagan, 1982) and other enforcement situations in which enforcers and subjects interact frequently (Muir, 1977; McCleary, 1975) have found that cooperative strategies play an important role in enforcement behavior.

The extensive use of both strategies has been documented in many regulatory arenas, and underlying assumptions about compliance problems have been discussed in Kagan and Scholz (1984). This article is concerned not with the empirical frequency with which these strategies are used, but rather with explaining the often overlooked relationship between the two strategies and "voluntary compliance" by regulated firms. The ecological extension of deterrence theory developed here analyzes the evolution of enforcement and compliance strategies between enforcers and those subjected to enforcement within a given enforcement arena. Social, economic, legal, institutional, and political factors affect the incentives facing both agency and subjects within each ecological niche, and thereby determine the advantages and likelihood of different strategies.

The game theory model I shall present analyzes conditions required for the emergence and maintenance of stable cooperative strategies despite short-term temptations for subjects to evade laws and for agencies to enforce them stringently against all subjects. As in standard deterrence theory, behavior is explained in terms of utility maximization subject to the limits of bounded rationality (Young, 1979). Compliance calculations include the probability of both formal sanctions and the kinds of social sanctions and indirect costs associated with accusations of illegal behavior (Anderson,

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1966). Cooperation refers to compliance in excess of what a rationally self-interested firm would engage in if confronted by an agency bent on deterrence.

Cooperation based on a normative commitment to the community and its laws could, of course, be analyzed within the deterrence theory framework by assuming that individual utility calculations include a community-oriented component (Margolis, 1982). A normative commitment to comply then implies that the community component outweighs narrow self-interested utility. But the model presented here demonstrates that cooperation can emerge even when no such normative commitment is present. Normative commitments are likely to evolve after a more egoistic form of cooperation is established and erode when ecological changes discourage cooperation (Axelrod, 1984), although the process is too complex to consider in this paper.

Cooperation, then, is viewed not as an altruistic strategy, but in the iterated prisoner's dilemma sense as a strategy which helps both individuals and enforcers to achieve higher utility in the long run by abstaining from temptations to maximize short-term gains. By applying recent advances in evolutionary game theory (Axelrod, 1984) to the ecology of enforcement, I will show that such cooperation depends on 1) enforcement strategies that are at once vengeful and forgiving, 2) subjects that are concerned about future encounters with enforcers, and 3) ecologically determined incentives that favor cooperation.

The model provides a research framework capable of uniting the disparate traditions of deterrence and compliance research. Furthermore, by considering simultaneously the incentives facing both firms and agencies, the model provides a unified theoretical perspective for incorporating recent studies of enforcement agency behavior into research traditions emphasizing criminal behavior. Although this article focuses primarily on cooperation in regulatory arenas, where our theoretical understanding is most lacking (Kagan and Scholz, 1984), the analysis can be applied to a range of problems in other areas of law and deviance. To encourage further application, the basic assumptions and general operation of the model will be presented in considerable detail. The empirical specification of model parameters for application to concrete regulatory circumstances has been left for a future article, although hypothetical examples will be presented to clarify the model.

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Sections I and II of this article discuss the problematic relationship between deterrence and cooperative strategies and the resultant enforcement dilemma in regulatory environments. After the introduction, in Section III, of game theory techniques needed to analyze conditions required for cooperation, a simple model of regulatory enforcement is developed in Section IV to specify more precisely the general assumptions about factors influencing the social advantages of the combined cooperative and deterrence strategy. Finally, Section V considers limitations on cooperation arising from complexities likely to be encountered in the practice of enforcement.

I. DETERRENCE AND COOPERATIVE STRATEGIES IN REGULATORY ENVIRONMENTS

Deterrence and cooperative enforcement strategies have frequently been viewed as opposing styles of regulatory enforcement (Kelman, 1982; Shover *et al.*, 1984) and have been advocated by opposing regulatory interests. The distrust of business that spurred the growth of social regulation in the 1960s suggested a need for deterrence strategies, while current concerns with excessive regulatory costs tend to revive the more traditional focus on cooperation and voluntary compliance. Properly seen, however, these approaches need not conflict since each is appropriate for a different kind of firm.

The "bad" firm, like the hardened criminal, requires the harsh, legalistic treatment we associate with deterrence. To implement a deterrence strategy, inspectors keep a close watch on the firm, investigate all suspicious signs, and meticulously enforce the letter of the law. Supervisors seek immediate prosecution even for trivial technical violations, and courts impose maximum penalties for willful violations. Of course, limited enforcement and prosecutorial resources may force agencies to prosecute selectively and plea bargain with bad firms, but the objective of such selectivity and bargaining is to maximize the deterrent threat that can be mustered with available resources, not to cooperate with the firm.

The "good" firm, on the other hand, may be approached by the regulator in a spirit of cooperation. Like the good citizen in court, the firm is given the benefit of a doubt when wrongdoing is suspected. Regulatory inspectors come infrequently and work unobtrusively. Technical violations are overlooked if trivial, and legitimate reasons for noncompliance are accepted when warranted by circumstances. More serious violations are

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noted, but generous abatement periods are granted and reasonable attempts to correct the situation will forestall prosecution. When prosecution is necessary, fines are likely to be minimal, congruent with the good intentions of the firm.

It is generally agreed that cooperative strategies are most important when the complexity of compliance situations makes it impossible to specify in unambiguous legal rules the behavior required to achieve intended policy purposes (Nonet and Selznick, 1978; Carter, 1979). Rule-oriented deterrence strategies are inadequate for the new social regulatory agencies because

> legalistic enforcement cannot encompass in formal, enforceable rules the sheer diversity of the causes of harm that arise in a large technologically dynamic economy. The inspector who walks through a factory and faithfully enforces each regulation may not detect or do anything about more serious sources of risk that happen to lie outside the rulebook; at the same time, he alienates the regulated enterprise and encourages noncooperative attitudes (Bardach and Kagan, 1982: 123).

In such situations, cooperative enforcement can lead to greater social benefits through flexible enforcement. Cooperative enforcement helps overcome the unavoidable problems of underinclusive and overinclusive regulations by allowing a firm to ignore technical violations in situations where compliance would contribute little to reducing harms. In return, corrective measures beyond minimal legal requirements are elicited in situations where harms can be reduced in a more cost-effective way.

Even when such tradeoffs are not available, excessive compliance costs can be minimized by cooperative enforcement. Economists provide several reasons why most regulatory standards are not optimally efficient: a general standard does not take advantage of more cost-effective procedures available in individual plants and so is, at best, optimal only for the hypothetical average plant; central rule-makers know less and have fewer incentives than local management to find least-cost abatement techniques; efficiency considerations cannot be the only guide if standards are to be enforceable (Schultze, 1977; Dunlop, 1976). To the extent that firms cooperate by finding more efficient methods to achieve the ends specified in the standards and agencies cooperate by acknowledging tradeoffs and accepting effective, low cost, *ad*

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hoc methods in lieu of legally required ones, cooperation can achieve better outcomes for the agency at less cost to the firm.

In one extreme example, a California manufacturer saved millions of dollars by convincing the local air pollution agency that switching to a more viscous oil would reduce hydrocarbon emissions in a cold-rolling operation more than the installation of a legally required scrubber. More mundane tradeoffs occur daily when OSHA inspectors overlook the many technical violations they could cite at even the most safety conscious construction project, provided the contractor has taken reasonable safety precautions and is willing to correct glaring deficiencies at once.

In addition to the advantage of cost-saving tradeoffs, cooperative firms and agencies avoid the high legal costs incurred when coercive agencies battle evasive firms. And firms are more likely to share information on newly discovered problems not covered by regulations if agencies are likely to help solve the problem rather than promulgate simple rules and enforce them legalistically. Finally, agencies can shift scarce monitoring and prosecutorial resources from cooperative firms to bad firms, thereby increasing, through deterrence, the level of compliance among bad firms.

These propositions are neither new nor controversial, since studies have generally found that agencies use different enforcement strategies for good and bad firms. Inspectors in the British Factory Inspectorate routinely classify firms as cooperative or noncooperative (Carson, 1970). Pollution control officials decide on the appropriate level of response to a violation by considering the willfulness of the violation, the likelihood that it will recur, and the past behavior of the firm (Hawkins, 1984). Studies of U.S. agencies also report formal and informal methods for keeping track of troublemakers (Bardach and Kagan, 1982).

What is not well understood is why good firms do not exploit cooperative enforcement strategies. Chester Bowles (1971), drawing on his experience with the wartime Office of Price Administration, suggested that about 20 percent of all firms will comply unconditionally with any rule, about 5 percent are always going to disobey, and about 75 percent are also likely to comply, but only if the threat of punishing the incorrigible 5 percent is convincing. In other words, "voluntary compliance" by the largest percentage of firms depends in some way on attempting to deter the minority of bad firms.

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Other analysts have explained this conditional cooperation in terms of legitimacy, noting as do Kagan and Scholz (1984) that punishing unjustifiable violations is essential even for a "cooperative" enforcement strategy. Some firms undoubtedly comply out of civic duty, but it seems unlikely that the extent of voluntary compliance observed in regulatory arenas can be explained by legitimacy and civic duty alone. The model developed later explains this conditional cooperation without resorting to a firm's social commitments by analyzing the conditions under which stable cooperation is possible despite the enforcement dilemma.

II. THE ENFORCEMENT DILEMMA

The question of whether to adopt a cooperative or deterrence strategy is not easily resolved since cooperative enforcement may tempt even good firms to take advantage of lesser scrutiny in order to delay or avoid compliance costs. Many OSHA inspectors interviewed for the Bardach and Kagan (1982) study reported at least one experience of being duped by an opportunistic firm that had responded with surreptitious evasion to the confidently casual inspections that past cooperation had engendered. On the other hand, firms with exceptional safety programs have been frustrated by crusading inspectors who insist on expensive abatement procedures in situations where regulations are ambiguous and the expected reduction in harm is minimal. And agencies under public pressure to show results after some well-publicized catastrophe are likely to crack down on all firms regardless of past cooperative efforts. Thus, cooperative firms cannot be certain that they will not be the targets of strict, or even harassing, enforcement efforts.

Figure 1 illustrates the four ideal types of outcomes that arise from crossing flexible and coercive modes of enforcement with compliant and evasive firms. Payoffs are labeled with standard prisoner's dilemma terms referring to the temptation (t), reward (r for mutual cooperation), punishment (p for mutual defection), and sucker (s) payoffs. The firm's payoff is given at the bottom of each cell in small letters (t,r,p,s), and the agency's is given at the top in capitals (T,R,P,S). Each square is labeled descriptively from the firm's point of view.

When the enforcement agency is willing to be flexible and the firm voluntarily complies, firms can, as noted earlier, reduce compliance costs and the risk of sanctions while both firm and agency avoid expensive litigation. Thus, the expected

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Figure 1. The Enforcement Dilemma: Payoffs for Joint Compliance and Enforcement Decisions

FIRM'S INITIAL COMPLIANCE OPTIONS		AGENCY'S ENFORCEMENT OPTIONS: COOPERATIVE (goal-oriented)	AGENCY'S ENFORCEMENT OPTIONS: DETERRENCE (rule-oriented)
	COMPLY	R = 100 TONS VOLUNTARY COMPLIANCE r = −$2 million	T = 125 TONS HARASSMENT s = −$4 million
	EVADE	S = 50 TONS OPPORTUNISM t = −$1 million	P = 75 TONS LEGALISTIC BATTLES p = −$3 million

Agency payoffs (capital letters) represent expected amount of pollution reduced annually.

Firm payoffs (small letters) represent total expected annualized costs of compliance and sanctions.

Cell labels reflect the situation as seen from the firm's perspective.

The dilemma defined: T>R>P>S and t>r>p>s
2R>S+T and 2r>s+t

rewards for both agency and firm (R and r) from mutual cooperation exceed the punishment (P and p) that an evading firm and deterring agency can expect to receive when they confront each other in legalistic battles.

The specific conditions for which cooperation is preferable will be discussed later, but two California pollution cases that I investigated may help clarify why cooperation is advantageous. In one district cooperation between a firm and the enforcement agency resulted in production alterations that reduced hydrocarbon emissions to a lower level than the legally mandated scrubber at a considerably lower cost. For purposes of illustration the agency's reward for cooperation is estimated in Figure 1 to be an annual reduction in emissions of 100 tons. The firm's annualized costs, including planning, implementation, and maintenance expenses, were perhaps $2 million.

In a different district, costly legal battles over a similar rule delayed compliance, blocked the firm's modernization program for several years, and ultimately resulted in the installation of very expensive legally mandated pollution control equipment

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that reduced emissions at only one point in the production process. Annual emission reduction in this case was at best only 75 tons, in part because the firm, which had fought the agency all the way, installed the smallest legally acceptable scrubber and operated it at minimal levels of efficiency. The firm's annualized costs probably exceeded $3 million when litigation expenses, fines, and opportunity costs from delayed modernization are added to the installation and maintenance costs of the scrubber.

A hypothetical extension of this example points out the difficulty in achieving cooperation even though both firm and agency may prefer it. If the agency cooperates, the firm may mislead the agency about the extent of emission reduction and take advantage of flexible enforcement procedures that can be readily evaded. This situation corresponds to the opportunism cell in Figure 1. Here the agency unknowingly accepts procedures that reduce emissions by only 50 tons. The firm's costs in this situation, $1 million, are the lowest possible in Figure 1 and thus the most tempting (t). The level of pollution reduction is the lowest and least appealing for the agency, which if it learns what has happened, will rightly feel that it has been played for a sucker (S).

On the other hand, the firm may cooperate by developing and implementing innovative pollution-saving production techniques only to have the agency insist later that the legally required scrubber be installed as well. From the firm's point of view this is harassment, since it pays for most of the cooperative effort (say, $1.5 of the full $2 million) as well as the mandated scrubber (say, $2.5 million). Avoiding the legal and opportunity costs associated with the punishment payoff (say, $0.5 million) recoups only a fraction of these expenses. Thus, when the firm cooperates only to have the agency adopt a rule-oriented deterrence strategy, the firm pays the highest cost sucker payoff (s) of $4 million, while the agency gets the advantage of two sources of control and receives the highest and most tempting payoff (T), perhaps a 125 ton reduction in pollution.

These two hypothetical scenarios were in fact of great concern to the cooperating California firm and agency, because they both had to undertake cooperative actions without being certain of the other's sincerity. The corporation had to develop alternative abatement techniques without formal agency approval, while the agency had to give tacit consent without knowing how accurate the company's estimates of pollution

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reduction were. Thus, the firm sent formal letters outlining progress which the agency would only discuss unofficially by phone.

As Williamson (1975) has argued in a broader context, the combined problems of information disparities and opportunism common in enforcement relationships inhibit beneficial cooperation in a wide range of exchange relationships. Whenever the temptation to cheat is great and no relationship of trust has been established, the agency is always safer choosing deterrence while the firm is safer choosing evasion. Then the worst either actor can do is get the punishment payoff, and if the other side is foolish enough to risk cooperation, the higher temptation payoff is returned.

The problem of establishing mutual cooperation under the conditions in Figure 1 is at the heart of the prisoner's dilemma. In a single encounter, cooperation is indeed unlikely. But when the same players face each other in repeated games, cooperation is both theoretically plausible and observable in experimental situations (Axelrod, 1984). The model developed in this paper analyzes regulatory enforcement as a repeated enforcement game. The analysis shows how cooperation can be rooted solely in self-interested behavior and clarifies the relationship between cooperative and deterrence strategies required to sustain mutual cooperation. Furthermore, by viewing "trust" as the development of long-term cooperative strategies in the continued game, the model specifies the conditions under which trust is likely to break down.

III. WHEN COOPERATION IS POSSIBLE

Of the many approaches to repeated prisoner's dilemma games, Axelrod's (1984) work, with its emphasis on strategies, matrix values, and discount rates for future payoffs, provides what is perhaps the most useful foundation for a model of the enforcement process. A player's strategy is the rule that specifies what choice the player will make in every round of a repeating game against any possible opposing strategy. Strategies may be simple rules such as "always defect" (DD) and "alternately defect and cooperate" (DC), or complex rules which use the history of play to analyze the other player's probable strategy and determine the optimal response for the next round. Sophisticated strategies could include planned tests of the other's tendency to retaliate or attempts to lull the opponent into a false trust. As Axelrod (1980a; 1980b; 1981) has shown, one of the most robust strategies is the well-known rule

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of tit for tat (TFT): cooperate until the other player defects and then do in the next round what your opponent did last. In this section we shall see that the enforcement dilemma can be overcome when cooperative and deterrence approaches to enforcement are combined in a TFT strategy.

A. The Formal Advantages of TFT

Given any strategy and any payoff matrix, we can calculate the outcome and thus the payoffs in all rounds against any other strategy. If the discount parameter (w) of a given player is also known, the current value of that strategy for that player can also be calculated. The discount parameter is the product of two factors that jointly determine the current value of future payoffs: the first is the standard discount rate used to determine the current value of future rewards, and the second is the perceived probability in any given round that there will be another round. If a round is perceived to be the last, w is 0.

A TFT player facing a TFT opponent, for example, cooperates initially and continues to cooperate in succeeding rounds since the opponent also continues to cooperate. The current value of the first round payoff for mutual cooperation is the reward r (see Figure 1), the second round is r discounted by w, the third round is twice discounted (w^2r), and so on. Thus, the current expected value of the TFT strategy against TFT, or V(TFT|TFT), is

$$V(TFT|TFT) = r+wr+w^2r+. . . = r(1+w+w^2+. . .) = \frac{r}{1-w}.$$

Since a TFT opponent will always cooperate with any "nice" strategy (that is, any strategy which is never first to defect), all nice strategies receive this same cooperative score. Similarly, the value of DD against TFT is

$$V(DD|TFT) = t+wp+w^2p+. . . = t + \frac{wp}{1-w},$$

since DD will receive the temptation payoff, t, in the first round and the punishment payoff, p, in all succeeding rounds. The value of DC against TFT is

$$V(DC|TFT) = t+ws+w^2t+. . . = (t+ws)(1+w^2+w^4. . .) = \frac{t+ws}{1-w^2},$$

since DC's payoffs against TFT alternate between temptation, t, and sucker, s. By rearranging the above expressions, it can be seen that

$$V(TFT|TFT) > V(DD|TFT) \text{ whenever } w > \frac{t-r}{t-p},$$

$$V(TFT|TFT) > V(DC|TFT) \text{ whenever } w > \frac{t-r}{r-s}.$$

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Thus, TFT or any other nice strategy will do better than DD or DC against TFT as long as w is sufficiently large. Axelrod (1981: 311-12) has shown that no strategy can do better than TFT against TFT if DD and DC cannot. To rephrase Axelrod's results, no strategy can do any better than a nice strategy against a TFT opponent as long as

$$w > \max\left(\frac{t-r}{t-p}, \frac{t-r}{r-s}\right).$$

The smallest value of w that satisfies this inequality is the *minimal cooperative value*. Axelrod's result indicates that, when confronted with a TFT strategy, any firm with a discount parameter greater than the minimal cooperative value for the particular payoff matrix it faces will gain its highest expected value by complying from the first round onward. But what if a firm reevaluates its strategy in the midst of a continuous game, as is likely in enforcement situations?

We can extend Axelrod's results by noting that if the firm cooperated in the round prior to reevaluation, the values of all strategies against TFT will remain unchanged. If the firm evaded, however, the TFT agency will choose deterrence in the next round and the scores for different strategies become:

$$V(CC'|TFT) = s+wr+w^2r+\ldots = s + \frac{wr}{1-w},$$
$$V(DD'|TFT) = p+wp+w^2p+\ldots = \frac{p}{1-w},$$
$$V(CD'|TFT) = s+wt+w^2s+\ldots = \frac{s+wt}{1-w^2},$$
$$V(DC'|TFT) = p+ws+w^2t+\ldots = p + w\frac{s+wt}{1-w^2}.$$

Following the same procedure as above, CC′, the strategy of cooperating in all rounds, gives a higher score than any of the other strategies being evaluated after a previous defection whenever[1]

$$w > \max\left(\frac{t-r}{r-s}, \frac{p-s}{r-s}, \frac{p-s}{t-p}\right).$$

[1] This condition is actually more stringent than required, since the specific condition for V(CC′|TFT) > V(DC′|TFT) is given by

$$w > \frac{-(r-s) \pm \sqrt{(r-s)^2 - 4(p-s)[(t-r)-(p-s)]}}{2[(p-s)-(t-r)]}.$$

A more informative solution can be found by noting that V(CD′|TFT) > V(DC′|TFT) whenever

$$w > \frac{p-s}{t-p}$$

and that V(CC′|TFT) > V(CD′|TFT) whenever

$$w > \frac{t-r}{r-s}.$$

Thus, as long as w is greater than both expressions, or

$$w > \max\left(\frac{p-s}{t-p}, \frac{t-r}{r-s}\right),$$

we know that V(CC′|TFT) > V(CD′|TFT) > V(DC′|TFT).

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Combining the two criteria, a firm is always better off switching to a cooperative strategy in any round against a TFT agency as long as:

$$w > \max\left(\frac{t-r}{t-p}, \frac{t-r}{r-s}, \frac{p-s}{t-p}, \frac{p-s}{r-s}\right).$$

This can be reduced to just two conditions which will always dominate the others as long as $t > r > p > s$, so in a repeated enforcement situation our final formulation of the minimal cooperative value is

$$w > \max\left(\frac{t-r}{r-s}, \frac{p-s}{t-p}\right).$$

In sum, a cooperative solution to the enforcement dilemma is possible as long as a firm's concern for the future is greater than the minimal cooperative value determined by the differences between payoffs. The smaller the minimal value, the more likely that a firm, even one with little concern for future payoffs (that is, low discount parameters), will find it in its best interest to cooperate, as will be illustrated below with numerical examples. If we hold the highest and lowest payoffs (t and s) constant, it can be seen from the formula that the minimal cooperative value grows smaller, and thus the probability of cooperation increases, as the penalty payoff approaches the sucker payoff, or $p \rightarrow s$, and the reward payoff approaches the temptation payoff, or $r \rightarrow t$.

B. Practical Advantages of TFT

Returning to our initial example of the enforcement dilemma as illustrated in Figure 1, we can now see that the agency can elicit cooperation in the continued "game" by combining cooperation and deterrence in a simple TFT strategy: use deterrence against all firms that evaded in the last round and cooperate with all other firms.

By using the firm payoffs from Figure 1 in the equation for minimal cooperative conditions, we note that the firm will be better off cooperating as long as

$$w > \max\left(\frac{t-r}{r-s}, \frac{p-s}{t-p}\right) = \max\left(\frac{(-1)-(-2)}{(-2)-(-4)}, \frac{(-3)-(-4)}{(-1)-(-3)}\right)$$

$$= \max\left(\frac{1}{2}, \frac{1}{2}\right) = 0.5.$$

Since the enforcement game is almost certain to continue as long as the firm and agency survive, the w factor in this case is the rate at which future cash flows must be discounted to get the current value of future rewards. The discount rate for corporations reflects the cost of capital, which financial experts

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estimate to be around 18 to 20 percent for an average industrial corporation (Garrison, 1979: 534). A 20 percent cost of capital would translate into a discount parameter of w = 0.8, well above the minimum 0.5 required for cooperation in our example. At least in this case, TFT should enable the agency to gain the higher Reward payoff rather than the Penalty payoff with all but the most hard-strapped firms.

Experiments with human subjects have generally found TFT to be an effective strategy for achieving stable cooperative solutions under a range of prisoner's dilemma conditions (Oskamp, 1971; Wilson, 1971). These findings are reinforced by Axelrod's round robin computer simulation tournaments (1980a; 1980b), which pitted strategies submitted by game theory experts against each other in matches lasting approximately 200 rounds, with the least successful strategies eliminated at the end of each match. The results showed that, although TFT is not necessarily the best strategy in every situation, its ability to elicit cooperation against a wide range of strategies enables it to consistently outperform other strategies.

Axelrod's analyses of the tournament's best-performing strategies attribute TFT's robustness to several positive characteristics an agency's enforcement strategy might emulate. As a "nice" strategy (one that does not use deterrence until after a firm defects), TFT gains the full advantage of mutual cooperation with all firms pursuing nice strategies. As a vengeful strategy which retaliates immediately, it gets stuck with the sucker payoff only once against firms that evade in every round. Yet as a forgiving strategy it responds almost immediately if a previous evader begins to comply, thereby restoring the benefit of mutual cooperation rather than the lower payoffs of mutual defection.

Furthermore, the simplicity of TFT makes it easily recognized by an opponent. If the goal of the game were to get a higher score than the opponent, this transparency would be disastrous, since an opponent would try to maximally exploit the strategy's weakness. TFT does not outperform the opposing strategy, but it either aids or punishes both itself and its opponent. An exploitative firm would know that a TFT agency was certain to retaliate and that if it continued to evade both it and the agency would continue to receive the lower legalistic payoff. TFT's ability to elicit cooperation benefits both players by assuring the reward payoff for both. Thus, TFT's most significant advantage lies in its ability to elicit

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cooperation while discouraging exploitation by stealthy evaders. This ability not only assures an agency of obtaining cooperation with all "nice" firms that cooperate initially, but it also encourages cooperation from initially evasive firms once they recognize that they can do no better than cooperate. If the payoffs in Figure 1 were true for all firms in an enforcement arena, only foolish and hard-pressed firms would continue to defect against a TFT strategy.

IV. A MODEL OF THE ENFORCEMENT GAME

Now that the general approach to cooperation in regulatory settings has been introduced, an evolutionary game theory model will be developed to specify more precisely the assumptions about regulatory enforcement that are sufficient to explain cooperation. A hypothetical example involving OSHA will be used to illustrate the model. The model portrays the behavior of one agency and a number of firms within the agency's regulatory jurisdiction. Other relevant institutions are treated as part of an environment that affects choices by the firms and agency only insofar as it affects incentives. Thus, outside prosecutors, courts, political actors, and other relevant institutions help determine the payoffs firms and agency will get for any choice of strategies. Lax prosecutors, lenient courts, or the prospect of favorable political intervention, for example, will increase a firm's incentive to evade.

In order to focus on the enforcement relationship, the model relegates all political and rule-making activities of firms, agencies, and other actors (including groups benefiting from the policy) to the same exogenous environmental status. Enforcement decisions are organizationally distinguishable from rule-making or political activities in agencies and corporations alike (Scholz, 1981), and are assumed to be analytically distinguishable as well.

Within this ecological niche, firms and the agency play a repeated enforcement game in which the players' payoffs depend on their joint choice. Initially, we will assume that the agency is solely concerned with maximizing net compliance benefits for society, or benefits minus enforcement costs (cf. Viscusi and Zeckhauser, 1979). Firms are assumed to be solely interested in minimizing expected costs and sanctions. Environmental factors affecting these incentives and agency enforcement budgets are initially assumed constant, so payoffs for firm and agency will vary only as a result of mutual choice.

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Consider the simple two-person game between one firm and one enforcement agency. In each (arbitrarily defined) time period, the firm chooses some level of compliance activity and the agency assigns some level of enforcement to the firm. Each player must choose without knowing what choice the other is making, although by the end of the period, after it is too late to change the current round's choice, both know what the other has chosen and both know the costs and benefits imposed on them during that period.[2] Since the game is likely to continue as long as the firm survives, each player's choice in the current round is likely to influence the other player's choice in future rounds.

A. Assumptions about Compliance Outcomes

The model recognizes that the firm's options range from complete evasion to full compliance, while the agency's choices range from minimal to extensive levels of enforcement. Figure 2 illustrates one possible enforcement situation. The social value of expected compliance outcomes (vertical axis) is determined jointly by the agency's choice of enforcement level (horizontal axis) and the firm's choice, represented here by four different levels of compliance options (the curves labeled $y_1, y_2, y_3, \ldots, y_n$). The level of enforcement increases to the right along the horizontal axis, and compliance increases with higher compliance curves, so y_2 is a more cooperative or compliant option than y_1. Any enforcement situation can be represented in this manner as a function, $F(x,y)$, that indicates the expected social value of compliance benefits resulting from the choices made by the agency (x) and the firm (y).

Depending on the compliance option chosen, the firm complies with a number of regulations and tries to evade others, and the agency detects and forces abatement of a certain percentage of the firm's evasionary tactics during the period. For example, if the agency chose enforcement level x_2 and the firm chose compliance option y_1 in Figure 2, the expected value of compliance benefits by the end of the period would equal $F(x_2,y_1)$ = \$9,800. The shape of these curves, and thus the benefits resulting from any pair of firm and agency choices for a given function, is determined by available evasive

[2] Given the long delays between detection and sanctioning of violations, we assume in this analysis that the expected outcome of legal procedures is known at the end of the period, not that the penalty has actually been imposed. Although court strategies could be analyzed as a separate game between firm and agency, they are not considered in this simple analysis.

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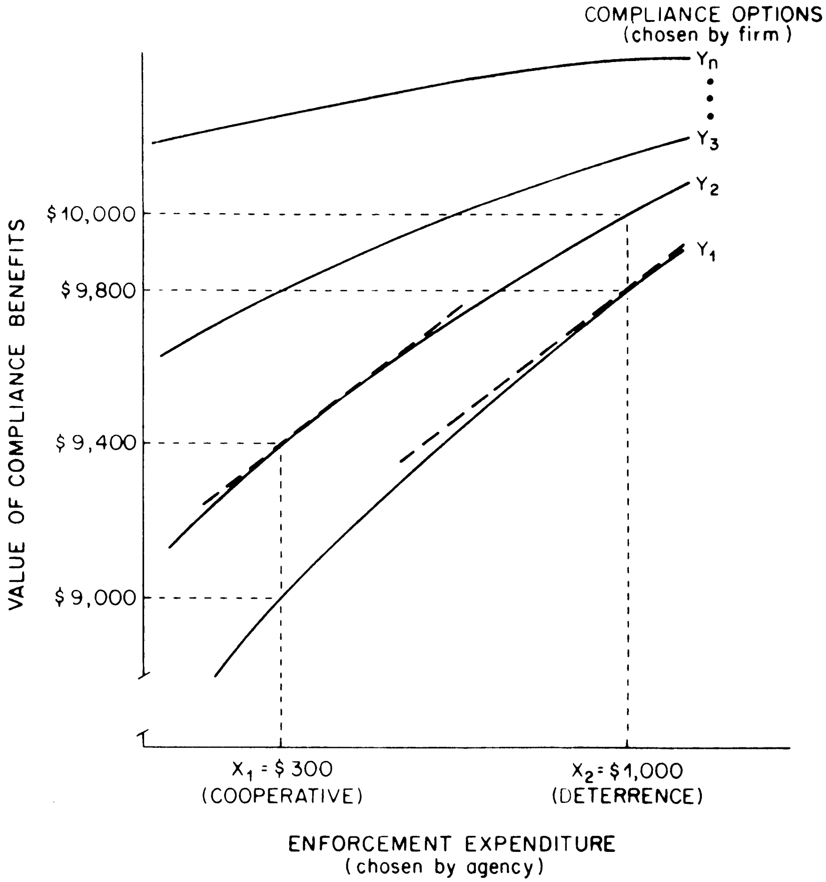
Figure 2. Expected Social Benefits from Compliance Outcomes for Compliance and Enforcement Choices



and enforcement technologies together with the environmental conditions in the particular enforcement niche.

For ease of analysis this model combines monitoring and prosecuting activities in a single enforcement choice, with an optimal mix assumed for any given level of activity. Lower enforcement levels correspond to less expensive cooperative strategies while higher levels correspond to more expensive deterrence strategies. This oversimplification does not capture the qualitative differences between the two strategies as discussed previously, but it allows us to emphasize critical differences in costs or resource requirements. Thus, the horizontal axis measures the cost of enforcement activities during the period. Each point, which is to say any given expenditure level, is associated with a different repertoire of

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enforcement activities that an agency can bring to bear on a particular firm.

The curves in Figure 2 illustrate four traits that all short-term enforcement situations are assumed to have in common.[3] First, for any level of compliance, benefits increase as enforcement expenditures increase. More enforcement resources enable the agency to detect and force the abatement of a greater percentage of attempted evasions, so cooperative enforcement (x_1) will result in lower benefits than deterrence (x_2) against any given compliance option short of full compliance. Consider a firm that chooses a very evasive option, y_1, against OSHA. If OSHA chooses a level of enforcement near zero, no compliance benefits would be achieved. Yet in this situation even low levels of monitoring and abatement pressures (x_1), if focused on the most important problems, could produce significant benefits, equal to $F(x_1,y_1)$ = \$9,000. Higher levels of enforcement, x_2 for example, yield even higher compliance benefits, equal to $F(x_2, y_1)$ = \$9,800.

Second, assuming, as the figure does, that an agency deploys its resources most efficiently at each level of enforcement, as more enforcement resources are used, the problems tackled will involve less harmful and harder to detect evasions, and the additional social benefit from higher levels of enforcement will decrease. Preventing firms from exposing workers to illegally high levels of toxic substances during normal production might be accomplished with moderate monitoring activities, for example; but preventing exposure during short periods of exceptionally high levels of production would require considerable additional monitoring resources in return for very small savings in overall exposure (assuming no important "thresholds" exist). In short, the second assumption is that the marginal return on enforcement resources diminishes at higher levels of enforcement.

Third, for any given level of enforcement, the more compliant the firm, the greater the resultant social benefits.

---

[3] Mathematically, all the assumptions are implicit if function F is restricted to the set of continuous, non-negative functions of two variables for which the first partial derivatives are positive and second derivatives negative for each variable, and the partial derivative $\partial^2 F/\partial x \partial y$ is also negative. The four traits discussed in the text can be summarized in the order in which they appear as:

1) If $x_2 > x_1$ then $F(x_2,y) > F(x_1,y)$.
2) If $x_2 > x_1$ then $\partial F(x_2,y)/\partial x < \partial F(x_1,y)/\partial x$.
3) If $y_2 > y_1$ then $F(x,y_2) > F(x,y_1)$.
4) If $y_2 > y_1$ then $\partial F(x,y_2)/\partial x < \partial F(x,y_1)/\partial x$.

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Since higher levels of compliance are associated with fewer attempts to evade, enforcement resources can be concentrated on the fewer remaining evasions. Consequently, compliance benefits for cooperative enforcement increase from $F(x_1,y_1)$ = \$9,000 to $F(x_1, y_2)$ = \$9,400 if the firm chooses y_2 instead of y_1.

But fourth, given any level of enforcement, the marginal return from the enforcement effort is less if it is directed at a more compliant firm than if it is directed at a less compliant one. Since a firm complying at level y_2 employs fewer and less harmful evasive tactics than one at y_1, there is less to be gained from targeting an enforcement dollar against the former firm than there is from taking aim at the latter. Put another way, an expensive "wall-to-wall" inspection will turn up more violations in an evasive than in a cooperative firm. Even a smaller, more selective inspection has a higher probability of finding something to prosecute in an evasive firm than in a cooperative one. Thus, for both x_1 and x_2, the marginal return to enforcement efforts will be less when the agency confronts firms choosing higher compliance options. Consequently, if the agency in our example switches from a cooperative to a deterrence strategy against a firm operating at y_1, the switch yields \$800 in increased social benefits. If the firm has been following the more compliant strategy of y_2, the same increase in enforcement intensity yields only \$600 in additional social benefits.

B. Agency Payoffs and Optimal Enforcement

The agency's payoff, as noted earlier, is equated here with the social value of compliance benefits minus enforcement costs. For example, the agency's payoff in Figure 2 for agency choice x_2 when a firm chooses y_1 equals $F(x_2, y_1) - x_2$ = \$9,800 − \$1000 = \$8,800. Because the agency is not, in this model, directly concerned with costs imposed on firms, the agency's optimal strategy does not necessarily lead to the optimal social outcome, which is the point on the enforcement scale at which marginal benefits equal marginal costs, including compliance and enforcement costs.

We can derive from our four simple assumptions the conventional wisdom that an agency is better off using cooperative enforcement (x_1) against complying firms and deterrence (x_2) against evading firms. If all firms were treated alike and x_2 were the average enforcement budget per firm available to the agency, x_2 would represent the "optimal level of enforcement" (Stigler, 1970) against firm option y as long as

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the marginal return or slope of y at x_2 were equal to 1 (indicated in Figure 2 by the line of dashes tangent to curve y_1). The line of dashes is the agency's indifference curve. Because of the assumption of diminishing returns for enforcement expenditures, any incremental investment above x_2 would cost more than it would return in increased benefits, and any decrease would reduce benefits more than the savings in enforcement costs. Stated in a different way, the point of tangency between the agency's indifference curve and any compliance option curve is the point at which the agency's payoff for that compliance option is optimal.

The agency could do even better, however, if it could convince firms to choose a higher level of compliance, say y_2 instead of y_1. Optimal enforcement for y_2 in Figure 2 is at x_1, where the marginal return or slope of y_2 equals one. Net enforcement benefits at this new level of optimal enforcement equal the total social benefits of $9,400 minus the agency's cost of $300, or $9,100. This is greater than the net benefits of $9,800 minus costs of $1,000, or $8,800, which is the return at the optimal level of enforcement when the firm adopts an evasive (y_1) strategy. Note that the agency would have been better off had the firm switched from an evasive to a compliant strategy even if its strategy had remained constant at x_2. However, while this would have returned higher social benefits ($10,000 versus $9,400 at x_1, y_2), it would not have been optimal because the marginal return (or slope of y_2) would be less than one. In other words, the $700 saved by the agency in enforcing the law less rigorously against the more compliant firm outweighs the diminution of $600 in social benefits. Where the four assumptions specified above hold, net benefits at optimal levels of enforcement will be greater, and optimal levels of enforcement will be less, for higher compliance options.[4]

Thus, an agency using a combined strategy can achieve its highest return by finding the highest level of cooperation that firms are willing to accept when they are enticed by an offer of the lowest optimal enforcement level and induced by the threat of future retaliation should they fail to comply at the level of cooperation defined by the agency. Such an agency would use cooperative enforcement against any cooperating firms and a deterrence strategy against firms that have most recently

[4] This follows mathematically from the above four assumptions (Scholz, 1983):

if $y_n > y_1$, $\partial F(x_n,y_n)/\partial x = 1$, and $\partial F(x_2,y_1)/\partial x = 1$,
then $x_n < x_2$ and $F(x_n,y_n) - x_n > F(x_2,y_1) - x_2$.

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shown themselves unwilling to cooperate. We shall refer to the cooperative level of enforcement in a combined strategy as C (= x_1 in Figure 2), and to what the agency sets as the minimally acceptable level of compliance (i.e., the level that will justify a C response) as c (= y_2). The initial enforcement level when deterrence is called for is D (= x_2), and the level of evasion that is the firm's optimal tactic for any round in which an agency chooses D is e (= y_1). An agency following the TFT combined strategy will use deterrence level D against any firm not complying at or above c in the immediate past encounter, and cooperative enforcement at level C against all other firms.

C. *Firm Payoffs and Factors Affecting Cooperation*

The next step is to clarify the factors affecting a firm's willingness to cooperate with regulatory agencies. In the situations we are interested in, compliance benefits accrue primarily to others in society and not to the firm, since otherwise the firm would comply out of self-interest, and there would be no need for regulations or enforcement. Thus, firm payoffs are assumed to be negative. They are determined primarily by the costs of compliance or avoidance, which increase as enforcement effectiveness and the rate of diminishing returns of compliance investments increase, but decrease with the cost tradeoffs and sanction adjustments that are available to cooperative firms. By noting how each factor affects the firm's temptation, reward, punishment, and sucker payoffs when the agency employs its combined TFT strategy, we can see how each factor affects the critical cooperative value discussed in Section IIIA and what this implies for the level of "voluntary compliance," c, achievable with the combined strategy.

Consider first the simple case in which no sanctions are incurred and compliance costs exactly equal the value of benefits. Then enforcement effectiveness, as indicated by the benefit function, alone determines the firm's payoffs. In Figure 2, for example, assume that the agency's optimal combined strategy is to use cooperative enforcement (C = x_1) if the minimally satisfactory compliance level (c = y_2) is achieved and that the firm's best option if the agency chooses deterrence (D = x_2) is to attempt to evade (e = y_1). In this situation the firm's possible costs duplicate the order of payoffs in the prisoner's dilemma:

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$$\begin{array}{llll} \text{Temptation:} & t = -F(C,e) & = & -\$9{,}000 \\ \text{Reward:} & r = -F(C,c) & = & -\$9{,}400 \\ \text{Punishment:} & p = -F(D,e) & = & -\$9{,}800 \\ \text{Sucker:} & s = -F(D,c) & = & -\$10{,}000. \end{array}$$

Cooperation would in this case be in the firm's interest whenever the firm's discount factor w is greater than the minimal cooperative value for F, which as I have shown is:

$$w_F = \max\left(\frac{t-r}{r-s}, \frac{p-s}{t-p}\right) \text{ or, in this case, } w = \max\left(\frac{400}{600}, \frac{200}{800}\right) = \frac{400}{600} = 0.67.$$

Given the relatively low value of w_F, cooperation in this case will be in most firms' best interest even without considering cost tradeoffs and sanctions because the benefits (and thus, by assumption, the firm's costs) associated with mutual cooperation, F(C,c), are less than those associated with deterrence and evasion, F(D,e).

An interesting implication of this model is that if methods for monitoring essentially cooperative firms become more effective in comparison to methods for monitoring evasive firms, the incentive to cooperate will diminish. This makes intuitive sense because one of the benefits of cooperation is freedom from close supervision and the savings this allows. To see how this follows from the logic of our model, suppose that compliance benefits for every level of enforcement remain as they are in Figure 2 for the evasive option e but are increased by some value k for compliance option c. That is, for any enforcement level x, the expected benefits are now given by a new function G such that G(x,e) = F(x,e) and G(x,c) = F(x,c) + k. The levels of cooperative enforcement and compliance for the combined strategy need not be changed, since the marginal return on enforcement at c will still equal one. But now the social benefits and the firm's corresponding costs of cooperation are increased by k, making the reward and sucker payoffs less attractive. If k = \$150, for example, the firm's payoffs for G would be

$$\begin{array}{llllll} \text{Temptation:} & t_G & = t & = -\$9{,}000 & = & -\$9{,}000 \\ \text{Reward:} & r_G & = r-k & = -\$9{,}400 - \$150 & = & -\$9{,}550 \\ \text{Punishment:} & p_G & = p & = -\$9{,}800 & = & -\$9{,}800 \\ \text{Sucker:} & s_G & = s-k & = -\$10{,}000 - \$150 & = & -\$10{,}150, \end{array}$$

and the minimal cooperative value would increase from 0.67 to 0.92.[5]

5

$$W_G = \max\left(\frac{t_G-r_G}{r_G-s_G}, \frac{p_G-s_G}{t_G-p_G}\right) = \max\left(\frac{t-r+k}{r-s}, \frac{p-s+k}{t-p}\right) = \max\left(\frac{550}{600}, \frac{350}{800}\right) = 0.92 > w_F.$$

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Since the minimal cooperative value for G will always be higher than for F, firms with discount parameters between w_F and w_G will cooperate when enforcement effectiveness is at level F but not when it is increased to G. Furthermore, discount parameters will inevitably be less than one, since a parameter value of one represents the limiting case in which the firm makes no distinction between current and future payoffs and has a discount rate of zero. As the minimal cooperative value increases toward one, it becomes increasingly unlikely that any firm's discount parameter will be below the minimum, and thus the likelihood that firms will respond to the combined strategy by cooperating decreases. In the extreme case where the increase in the cost of cooperation, k, makes the reward payoff more costly than punishment, or k = $400 for our initial function F, the firm will obviously never prefer cooperation unless other inducements are applied. The more general point is that if an agency using the combined strategy is facing a set of firms with a given w, it should recognize that there is some level of compliance above which cooperation will not be in the firms' best interest.[6] In other words, the higher the standard of voluntary compliance set by the agency, the higher the corresponding minimal cooperative value and thus the greater the likelihood that cooperation will not be in the firm's best interest.

Of course, for socially beneficial regulations we would generally expect compliance costs to be lower than the social benefits gained by compliance, since otherwise compliance with the regulation would leave society as a whole worse off. More importantly, the return on compliance investments is likely to be characterized by diminishing returns, which is to say that the first dollars spent on compliance are likely to yield more social benefits than the last (Schultze, 1977; Baumol and Oates, 1979). This means that the costs incurred by the firm

[6] The proof that a maximum cooperative level c* exists for any w, initial point D,e, and function F meeting the assumptions noted above is somewhat more complex. Although the proof will not be given here, note that the assumptions about F ensure that t−p (= −F(C,e)−(−F(D,e))) > r−s (−F(C,c)−(−F(D,c))) and that t−r (= −F(C,e)−(−F(C,c))) > p−s(−F(D,e) −(−F(D,c))) = p−s, so it will always be true that: $\frac{t-r}{r-s} > \frac{p-s}{t-p}$. Thus, only the (t−r)/(r−s) term of the minimum cooperative value formula need be considered.

It can then be shown that as C decreases and c increases while $\partial F(C,c) = 1$ (which defines the condition for an optimal cooperative policy), the change in t−r is greater than the change in r−s. Thus, the ratio (t−r)/(r−s) will increase as c increases, resulting in a higher minimal cooperative value for higher c and correspondingly lower C. The minimum cooperative value formula thus determines a function that associates a maximum level of voluntary compliance, c*, with each value of w.

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per unit of social benefit increase with the level of benefits sought by the regulators.

We have already noted that the marginal returns on enforcement expenditures decrease at higher levels of expenditures, and thus that the agency maximizes net benefits by limiting enforcement expenditures to the level at which a one unit increase in enforcement expenditure produces one unit of increased compliance benefits. Although the agency is not directly concerned with the decreasing marginal returns on compliance investments, it is concerned with the firm's incentive to cooperate with its combined strategy. Since costs, not benefits, determine the likelihood of cooperation at any given standard of voluntary compliance, the agency must consider the effect of diminishing returns on the minimal cooperative value when setting the voluntary compliance standard.

Diminishing returns on compliance investments always lead to lower minimal cooperative values if, as in Figure 2, the deterrence solution yields greater benefits (\$9,800) than cooperation (\$9,400). Diminishing returns imply that the costs per unit of benefit increase at higher levels of benefits. The penalty payoff is affected by rising costs relatively more than the reward payoff, and the sucker payoff is affected most of all. Compared with the difference in benefits we have considered up to now, the difference in costs between punishment and reward payoffs relative to other payoffs will thus be greater, making cooperation more attractive.[7]

[7] More specifically, the initial assumptions about the function F ensure that F(C,e) < F(C,c) < F(D,c) and F(C,e) < F(D,e) < F(D,c), which corresponds to cost payoffs of the following order: t>r>s and t>p>s. Note that it is not necessarily true that r>p for all functions satisfying initial assumptions.

Since diminishing returns imply that per unit costs increase with the level of benefits, any function o for converting benefit levels of F to costs must therefore have the following ordering:

$$o_t < o_r < o_s \text{ and } o_t < o_p < o_s.$$

Therefore

$$\frac{o_t}{o_r} < 1, \quad \frac{o_t}{o_p} < 1, \quad \frac{o_s}{o_r} > 1, \quad \frac{o_s}{o_p} > 1.$$

Since t, r, p, and s are all negative,

$$\frac{\frac{o_t}{o_r}t - r}{t-r} < 1 < \frac{r - \frac{o_s}{o_r}s}{r-s} \quad \text{and} \quad \frac{\frac{o_t}{o_p}t - p}{t-p} < 1 < \frac{p - \frac{o_s}{o_p}s}{p-s}.$$

By rearranging the terms in these equations we get:

$$\frac{o_t t - o_r r}{o_r r - o_s s} < \frac{t-r}{r-s} \quad \text{and} \quad \frac{p-s}{t-p} < \frac{o_p p - o_s s}{o_t t - o_p p}.$$

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This implies that for two agencies facing the same enforcement situation (viz., the situation portrayed in Figure 2) in terms of benefits per enforcement expenditure, the agency whose regulations are associated with more rapidly diminishing returns should gain more cooperation. For example, consider the situation in which costs increase with the square of the benefits sought for firms facing Agency 1 and with the cube of benefits sought for firms facing Agency 2, or

$$\text{Agency 1: } A^*b^2 = c \qquad \text{Agency 2: } B^*b^3 = c,$$

where b is the benefit sought by the agency, c is the firm's cost for achieving b, and A and B are parameters determined by the firm's cost function. If we set A and B such that firm costs for the sucker payoff exactly equal social benefits, the payoffs facing each firm for the level of benefits indicated in Figure 2 are

Firm Payoff	Social Benefit	Firm Cost Under Agency 1	Firm Cost Under Agency 2
Temptation	$9,000	$ 8,100 (.90)	$ 7,290 (.81)
Reward	$9,400	$ 8,836 (.94)	$ 8,306 (.88)
Punishment	$9,800	$ 9,604 (.98)	$ 9,412 (.96)
Sucker	$10,000	$10,000 (1.0)	$10,000 (1.0)
Minimal Cooperative Value		0.63	0.59.

This example reflects the realistic conditions that costs never exceed benefits and that the costs per unit of benefit, indicated in parentheses, increase at higher levels of benefits. It also illustrates the point, demonstrated more conclusively in note 7, that greater rates of diminishing return are associated with lower minimal cooperative values. Note that under Agency 1, where costs per unit benefit range from 0.9 to 1, the cooperative value of 0.63 is lower than for the case of no diminishing returns (0.67, as indicated above), but higher than for Agency 2, where costs per unit benefit range from an even lower 0.81 to 1.

Although diminishing returns encourage cooperation in situations similar to Figure 2, our initial assumptions about compliance outcomes can lead to cases in which benefits are higher at cooperative outcomes (C,c) than at deterrence (D,e). In this case, the compliance costs associated with the reward payoff would be higher than those associated with the penalty

As discussed in note 6, only the first ratio affects the minimal cooperative value of F as long as $r>p$. In this case, diminishing returns decrease the minimal cooperative value for cost payoffs in comparison to the value based on benefits, which we have considered up to now. Note also that the decrease is more pronounced as diminishing returns increase, as indicated by an increase in the o_t/o_r ratio in comparison to the o_s/o_r ratio.

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payoff. No firm is likely to cooperate in this situation unless other components of the payoffs, namely cost tradeoffs and sanctions, lead to higher total cost for the penalty payoff than for the reward payoff. Since diminishing returns in this case result in a greater per unit cost at the higher "reward" level of compliance than at the punishment level, the agency that seeks to ensure that the cooperative solutions it favors are also favored by the firm must be especially willing to allow cost tradeoffs and/or especially diligent in seeking sanctions. In sum, diminishing returns increase the firm's incentives to cooperate when the level of social benefits at (C,c) is less than at (D,e), but otherwise decrease incentives.[8]

Cost tradeoffs lead to greater cooperative gains for the agency. If an agency promises cooperative firms that it will not be a stickler for rules so long as overall regulatory goals are achieved, the possibility that the firm can substitute lower cost methods of goal attainment for what is technically required will decrease the minimum cooperative value and thus increase the likelihood of cooperation and the maximum level of cooperation. In the terms of our model, the flexibility associated with cooperative enforcement C will reduce the firm's temptation and reward payoffs to a proportion, j, of what they would be without tradeoffs, but the other payoffs and the resultant social benefits will remain unaffected. For example, if tradeoffs reduced the costs in Figure 2 by 10 percent, the payoffs would be

Temptation:	jt =	0.9x(−$9,000) =	−$8,100
Reward:	jr =	0.9x(−$9,400) =	−$8,460
Punishment:	p =		−$9,800
Sucker:	s =		−$10,000.

The minimum cooperative value with cost tradeoffs is now 0.23.[9] Thus, a cost tradeoff of 10 percent leads to a considerable increase in the likelihood of cooperation, since firms with w between 0.23 and 0.67 in our example find it in their best interest to cooperate although they did not when cost tradeoffs were unavailable. Obviously, the greater the cost tradeoffs, the

8 Diminishing returns can also affect the firm's incentive to comply in a different way, familiar to most regulatory analysts. Firms that choose to cooperate when standards are easily achieved may have difficulty in doing so as standards continue to be raised, since diminishing returns mean that each time the standard is raised the marginal costs of compliance will be greater than they were in the past. At an earlier point than would be the case if returns did not diminish, compliance costs may exceed the firm's ability to pay. In terms of the model, the firm's concern with the future, w, is substantially diminished if it is uncertain about meeting current costs, and thus cooperation becomes less likely.

9 $$W_{Ftradeoff} = \max\left(\frac{jt-jr}{jr-s},\frac{p-s}{jt-p}\right) = \max\left(\frac{360}{1{,}540},\frac{200}{1{,}700}\right) = 0.23 < w_F.$$

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lower the critical cooperative value for a given combined strategy.

Sanctions decrease the critical cooperative value in two ways. First, the compliance efforts and "good intentions" of more cooperative firms are generally rewarded with lower penalties, thereby increasing the value of the reward and sucker payoffs in relation to the evasive payoff. Second, sanctions are higher as enforcement becomes more stringent because with more resources devoted to enforcement, the agency can discover more violations, improve the quality of evidence gathered, and more effectively plea bargain or prosecute. Consequently, the temptation and reward payoffs associated with lower levels of enforcement are relatively more attractive when agencies are prepared to devote substantial resources to the strict sanctioning of uncooperative firms.

To appreciate the formal implications of a realistic threat of sanctions, assume that the expected cost of sanctions for a noncooperator confronting a deterring agency is \$1,000. Assume that cooperative firms, thanks to their observed good behavior, may expect their penalties to be reduced by m dollars, which is set at \$150 in this example. Finally, assume that cooperative enforcement, thanks to the fact that fewer violations will be uncovered, leads to a reduction in sanctions of n dollars, or in this example \$450, in comparison to sanctions imposed by deterrence-oriented enforcement. Given these assumptions, the firm's payoffs for function F, including sanctions, equal

Temptation:	t − \$1,000 + n	= −\$9,550
Reward:	r − \$1,000 + m + n	= −\$9,800
Punishment:	p − \$1,000	= −\$10,800
Sucker:	s − \$1,000 + m	= −\$10,850,

and the minimal cooperative value with sanctions is 0.24.[10] This is considerably below the initial value of 0.67, as will always be the case for the sanction structure described above.

Two additional aspects of sanctions are noteworthy. First, the assumption that the firm's choice, e, is the best response to the agency's choice, D, implies that at e the marginal benefit of decreasing compliance cost ($\partial F(D,e)/\partial y$) equals the marginal cost imposed by the system of sanctions ($\partial \mathrm{Sanction}(D,e)/\partial y$).

10

$$W_{Fsan} = \max\left(\frac{t-r-n}{r-s+m}, \frac{p-s-m}{t-p+n}\right) = \max\left(\frac{250}{1{,}050}, \frac{50}{1{,}250}\right) = 0.24 < w_F.$$

As with tradeoffs, sanctions will always lower the critical cooperative value for a given enforcement situation; since $m > 0$ and $n > 0$ by the above assumptions, all numerator terms decrease while all denominator terms increase.

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In other words, compliance option e is the best response to enforcement option D because, if the firm is more evasive than it is at e, the expected increment in sanction costs will exceed the expected reduction in compliance costs. And if the firm is more compliant than it is at e, the additional compliance costs can be expected to exceed the savings from reduced sanctions. Thus, the choice (D,e) corresponds to the normal deterrence solution in which both agency and firm are pursuing optimal strategies. In game theory parlance, this choice pair corresponds to a Nash equilibrium in which neither opponent has an incentive to change its choice unilaterally.

Second, it is the marginal change in sanctions with respect to enforcement and compliance that affects cooperation, not the absolute level of sanctions. In the above example, the $1000 sanction that evasive firms can expect from deterring agencies (the penalty payoff) can be changed without affecting the minimal critical value. Only the m and n terms affect this calculation. Of course, the higher the sanction for the penalty payoff, the greater the potential difference in the sanctions faced by compliant or evasive firms or by firms confronting cooperative or deterring agencies. Furthermore, the example I have used assumes that the marginal changes in sanctions are independent, or that the advantages accorded compliant firms do not affect the advantage that comes from cooperative enforcement. If these two factors interact, the sanction cost savings enjoyed by compliant firms facing cooperative agencies may be more or less than m+n, which will bring about a corresponding change in the minimal cooperative value.

In summary, the minimal cooperative value for a combined strategy decreases as diminishing returns, cost tradeoffs, and appropriate sanctions increase, but increases as higher levels of voluntary compliance are sought by the agency. Lower minimal cooperative values imply that the likelihood of cooperation is increased and that higher levels of voluntary compliance can be achieved.

D. *Optimal Combined Strategies of Cooperation and Deterrence*

We can now specify the optimal combined strategy given the enforcement level that cooperative firms can expect, the availability of cost tradeoffs, sanctions, and rate of diminishing returns on compliance investments. To show that the combined strategy works better than relentless deterrence, we will first look at the deterrence solution for the enforcement

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situation. This solution yields the agency-firm choice pair (D,e). Each firm chooses to evade since this minimizes firm costs when the agency is committed to deterrence. The agency, on the other hand, chooses to effectuate its deterrence strategy by setting its average enforcement budget per year at D, the level that yields the greatest total returns against firms bent on evasion. Neither agency nor firm has any incentive to change its choice as long as the other's choice remains unchanged, since any deviation would reduce its payoff.

Yet this equilibrium is almost inevitably wasteful.[11] The agency's costs of monitoring and prosecution and the savings that can be realized by the firm through cost tradeoffs and reduced sanctions are likely to be such that both parties will be better off if the agency reduces its enforcement expenditures and the firm increases its level of compliance. The potential for such mutually advantageous accommodation is unlikely to extend to the limits of full compliance and no enforcement because beyond some compliance level, c, the agency's insistence on higher levels of compliance in return for lower levels of enforcement is likely to yield firm payoffs for which the critical cooperative value is lower than the firm's discount parameter, w. Put more simply, the firm will prefer mutual cooperation to deterrence so long as the agency's definition of cooperation does not demand too much compliance. What is "too much" depends on how the firm evaluates the payoffs it is likely to receive in future encounters with the agency.

If the agency can induce firms to comply at level c in return for cooperative enforcement at level C, it will have achieved the most it can expect and will have made both itself and the firms better off than they were at the initial deterrence solution. Such are the virtues of cooperation. Deterrence strategies will have to remain part of the agency's enforcement arsenal, but only for those firms that have refused to cooperate in their most recent encounters with the agency.[12] To allow evasive firms to gain the advantages of cooperative enforcement rewards opportunism and encourages continued noncooperation. To deter recent non-cooperators while rewarding compliant firms with cooperation is, on the other

[11] In game theory parlance, the Nash equilibrium at the deterrence solution is not likely to be Pareto optimal.

[12] Stated more formally, the agency can maximize net benefits by establishing the (lowest) optimal enforcement level (C) for the highest compliance option (c) consistent with cooperative solutions for the given enforcement situation; the initial deterrence level of enforcement (D) will then be used only for firms that did not comply at the cooperative level (c) in the last round, while the cooperative level (C) will be used against all other firms.

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hand, the optimal combined strategy provided firms expect to remain under the agency's watchful eye in the future.

If we assume that sanctions just cover the costs required to impose them, or if the difference in cost between the firm's reward and punishment payoffs is primarily due to cost tradeoffs rather than sanctions, it follows that society as a whole is better off with the combined strategy than with deterrence alone, since higher net benefits are achieved by the agency at lower costs to the firms. By taking advantage of the agency's incentive to reduce monitoring costs and the firm's incentive to reduce compliance costs, cooperative solutions to the enforcement dilemma eliminate some portion of the economic inefficiency inherent in the use of regulatory commands to achieve social benefits.

E. The Evolution of Cooperation

Now that we have shown that socially beneficial cooperative solutions exist in our model given a reasonable set of assumptions about compliance outcomes and payoffs, we must consider how they might come to be realized. Since we are discussing the evolution of cooperation, we must necessarily start with compliance patterns that are less than optimally cooperative because of some change in the environment, such as the passage of a new set of regulations. Following this change, let us assume a regulatory environment in which the goals, laws, players, and resources are likely to be relatively stable over the foreseeable future and an agency that has established a combined strategy appropriate for that environment. In such a setting, cooperation should evolve if certain assumptions about 1) the stability, 2) the mutation, and 3) the selection of strategies by firms are met.

First, we assume that firms' strategies as they respond to regulation are relatively stable over time. Because of the limitations of bounded rationality, firms (as well as agencies) require routines or "standard operating procedures" to cope with complex regulatory issues (Scholz, 1981). These routines determine the propensity of firms to evade or comply. Thus, the firm's compliance strategies depend on the beliefs, competence, and motivation of responsible employees and on the way that these factors have been institutionalized in protocols and routines.

Second, we assume that there are beliefs and motivations that can lead corporate officials to change compliance strategies. These officials are aware of alternative strategies

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that can be used against a particular regulatory agency, but their enthusiasm for change is dampened by pressure to resolve other issues, uncertainty about the utility of new strategies, and concerns for problems and disruptions caused by attempted organizational changes. Nevertheless, strategies are occasionally reviewed and changed, especially when dissatisfaction with company performance is high (Scholz and Rhee, 1984) or there is strong evidence that a different strategy, especially one used by a competitor, would work better.

Third, we assume that there is a better than 50 percent probability that the new strategy will be more cost effective than the old. This assumption does not require undue wisdom on the part of firms, since the simple-minded imitation of more successful strategies used by competitors would give this result even if new strategies were randomly generated as unintended consequences of organizational changes. The closer firms come to the "omniscient rationality" assumed in economic theory, the greater the probability that they will select the most cost effective strategy when change is contemplated, and thus the more rapidly will cooperation be established at the level designated by the agency.[13]

It should be noted that this process requires no extraordinary capabilities on the part of the agency. The agency need only have two levels of enforcement routines and use the stricter routine in the next period against firms not currently complying at the accepted level. It does not need to know firm payoffs, since trial and error with different enforcement levels and a related standard of compliance should lead to cooperation at some level above the initial deterrence solution. Of course, the more knowledge the agency possesses about payoffs and the strategic considerations of the

[13] One might represent these three assumptions in our formal model by assuming that firms maintain existing compliance strategies until random events bring about a reevaluation. In each period every firm has some relatively low probability of reevaluating. Each reevaluating firm then has some probability greater than 0.5 of selecting one of many superior strategies that, in response to the agency's TFT strategy, meets the agency's minimal compliance standard in each round. It can readily be shown that any initial distribution of noncooperative firms using any conceivable strategies will become more cooperative in each round as long as the proportion of cooperators is less than the probability of selecting cooperation. Note the implication that firms already pursuing the optimal strategy may mistakenly change strategies, which in the long run limits the percentage of firms that cooperate. If firms are "smart" enough to choose the superior strategy 90% of the time, eventually approximately 90% of the firms will pursue cooperative strategies. However, if the events that trigger strategy reevaluation are not random but, for example, reflect the observation that others are doing better, eventually 100% cooperation may be approached. The analysis assumes, of course, that the agency does not set its cooperative compliance standard so high that compliance is not in the firm's best interest.

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combined strategy, the closer the agency can come to realizing the maximum benefits of the combined strategy.

V. THE LIMITS OF COOPERATION

We have now established that cooperative solutions to the enforcement dilemma can be socially desirable, and our model shows that cooperative solutions should evolve if possible future payoffs are substantial enough to overcome short-term temptations, if firms are able to adapt when more cost effective strategies seem possible, and if agencies pursue TFT strategies that encourage cooperation. But several studies note practical difficulties that the cooperative strategies employed by regulatory agencies encounter (Bardach and Kagan, 1982; Kelman, 1982). These limit the potential advantages of cooperation in some environments. We will now use our enforcement model to analyze several such limitations. In doing so, we will relax some of the simplifying assumptions of our model in order to briefly consider important complexities of regulatory enforcement.

A. Diversity of Firms

Thus far, we have assumed that all firms are alike, but it is implausible to expect that all firms will have the same payoff function or the same concern for the future, and the model does not demand this. Cooperation can evolve when firms differ, as long as each firm's discount parameter is greater than the critical value for that firm's payoffs. Of course, the diversity of firms in an enforcement arena complicates the agency's choice of enforcement levels. Ideally, the agency would partition firms into relatively homogeneous classes (e.g., industrial categories) and develop a different combined strategy for each class. In practice, considerable heterogeneity may be inevitable, particularly since different enforcement levels against different classes of firms might be regarded as discriminatory and so, as OSHA discovered in targeting particular industries for intensive enforcement efforts, create serious political and legal problems.

If an agency facing a group of diverse firms establishes a combined strategy that is optimal for the firm least likely to cooperate, the advantages of cooperation with firms that could be induced to comply at much higher levels would be largely lost. A standard that is optimal for the average firm will increase the benefits of cooperation but will make cooperation disadvantageous for firms with a lower than average concern

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for the future (w) or payoffs producing abnormally high minimum cooperative values. Thus, the more diverse the firms in any enforcement category and the less the ability of the agency to discriminate strategically among them, the fewer the firms that will be moved to compliance by an optimal combined strategy.

B. Strategic Limitations on Agency Enforcement Policy

The new federal regulatory agencies (OSHA, EPA) are commonly thought to be less cooperative than the older ones (Bardach and Kagan, 1982). Our model suggests two kinds of strategic limitations that could account for this. First, newness itself might lead to an undue emphasis on strict enforcement, since agencies may be ignorant of their best combined strategies or require some time to discover adequate enforcement levels and develop appropriate routines. Even if the agency employs an optimal combined strategy from the beginning, deterrence may be the dominant mode of enforcement until initially hostile firms discover the advantages of cooperation. Particularly if most firms learn the advantages of cooperation primarily by imitating the strategy of their more successful competitors, non-cooperators will be slow to perceive the benefits of voluntary compliance initially, when few firms are cooperating.

In addition, as Bardach and Kagan (1982) have observed, attempts in the last decade to curtail agency discretion and flexibility have made it more difficult, both politically and legally, for agencies to allow cost-saving tradeoffs or alter levels of enforcement for cooperative firms. By limiting their ability to pursue an optimal combined strategy, these "reforms" have reduced the advantages of cooperative enforcement for federal agencies.

Second, the large jurisdictions of these newer agencies hamper cooperation by increasing uncertainty in the firm-agency relationship. Such jurisdictions cut across numerous industrial and geographic boundaries, increasing the problems of heterogeneity discussed above. In addition, interactions between firms and these newer federal agencies are generally less frequent and intense than interactions with older, single industry agencies or with state and local regulators. For example, Bardach and Kagan (1982: 160) report that the number of inspection sites per inspector is much higher for deterrence-oriented OSHA (1:1515) than it is for agencies reputed to be more cooperative, such as the food processing

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and storage division of the FDA (1:77) or the California Milk and Dairy Division (1:63). Furthermore, broad-ranging newer agencies are generally required to monitor firms in different industries that employ a range of sophisticated technologies, while older agencies tend to specialize in a particular industry. High caseloads, combined with this task of inspecting very different industries, decrease an inspector's ability to be certain about an inspected firm's level of compliance.

As an agency's uncertainty about a firm's level of compliance increases, the firm's temptation to cheat increases as well. The agency could respond to such a situation by adopting a "trigger strategy" that would permanently deny cooperation to any firm with a record of minor evasions exceeding some "optimal" level of evasion as determined by the firm's rewards and the agency's uncertainty (Radner, 1981). Such a strategy would make occasional cheating less attractive to the firm, since the firm would face massive retaliation with a considerable loss of future rewards if it were caught. However, while the trigger strategy may be vengeful enough to prevent much minor cheating, it is not forgiving enough to encourage present evaders to cooperate. A firm on the agency's black list remains there forever.

Since minor violations are common if not inevitable and serious violations hard to uncover, agencies seek other indicators of a firm's willingness to cooperate in order to reduce their uncertainty over past behavior and expected future policies. Inspectors, in deciding how to treat a firm, consider such things as the attitudes and competency of managers, general conditions in the firm, the state of observable equipment, and other factors incidental to violations (Carson, 1970; Hawkins, 1984). If a firm appears cooperative, the agency is likely to reciprocate with cooperative enforcement, but uncertainty about the reality of cooperation undoubtedly leads to a "suboptimal" combined strategy in which the standard of voluntary compliance is set well below the full-information standard and enforcement resources considerably greater than the optimal cooperative level are required even for cooperative firms.

One way of introducing the problem of uncertainty into the model is to equate the game's enforcement period with the length of time required for the agency to know the firm's choice at some predetermined level of certainty. Greater uncertainty is represented by longer rounds. In the extreme case of complete uncertainty, the agency will never know the firm's

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choice, so the firm has every incentive to cheat. In effect, increased uncertainty decreases the firm's concern with the future and so limits the level of compliance at which cooperation can be sustained.[14]

C. Exploitative Agencies and Joint Resistance by Firms

If agencies are tempted to pursue exploitative strategies that have the potential to do better than TFT, cooperation becomes more problematic. The initial model avoids the problem of agency exploitation by assuming that the agency is primarily concerned with net enforcement benefits, which are maximized by the combined strategy. Assume an agency seeks to maximize total rather than net benefits for an environmentally determined fixed budget level, and the agency's payoffs are those given in Figure 1:

Temptation:	T = G(D,c)	=	125
Reward:	R = G(C,c)	=	100
Punishment:	P = G(D,e)	=	75
Sucker:	S = G(C,e)	=	50.

In such cases, the agency will not prefer cooperation even when the combined strategy is socially preferable unless

$$W > \max\left(\frac{T-R}{R-S},\frac{P-S}{T-P}\right) = \max\left(\frac{25}{50},\frac{25}{50}\right) = 0.5.$$

At this value cooperation would remain likely since the agency's reward payoff in Figure 1 is greater than the punishment payoff, and the agency's minimum cooperative value, W, is low enough that TFT will be superior to other strategies for most agencies. On the other hand, the agency would never prefer cooperation in the situation represented by Figure 2, since when enforcement costs are not taken into account, the agency's deterrence payoff, F(D,e), is greater than its best cooperative payoff, F(C,c).

Even when cooperation is preferable, an agency could attempt to increase its overall score by bullying cooperative

[14] Because greater uncertainty is represented by less frequent payoffs, the firm's concern for future payoffs, or w, automatically decreases. For example, the current value of a $100 payoff to be realized one year hence is $80 for a firm with an annual discount rate of 0.8. If uncertainty has the same effect as increasing the time between payoffs from one year to two, the current value of the same $100 payoff realized two years hence is only $64. Doubling the length of a round thus reduced the relevant future discount parameter from w = 0.8 to w = 0.64. The greater the uncertainty in a given enforcement arena, the greater the reduction in w below initial levels. The longer period does not, however, change the minimal cooperative value. Even if all payoffs are doubled, the ratio of differences which determine the minimal value will not be affected. In short, uncertainty effectively reduces the value of w for firms in the compliance arena, and consequently limits the level of compliance at which cooperation can be sustained. The less intense the interaction between agency and subject, the less the gains from cooperative strategies.

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firms. For example, it could attempt to sustain the occasional use of deterrence against cooperative firms by threatening never again to cooperate with firms that reciprocate with evasion. However, any strategy which increases the agency's payoff above that of mutual cooperation also decreases the firm's payoff and motivation for cooperating. Such exploitative strategies suffer from several weaknesses discussed at length by Axelrod (1984).[15]

The agency is particularly well situated with respect to a form of exploitation that Axelrod does not discuss. Namely, the agency can exploit its unique ability to structure the game with all firms by modifying the combined strategy. The initial model assumes that the agency uses any resources saved when evaders begin to cooperate for purposes other than enforcement. An agency may, however, reallocate fixed resources between cooperators and evaders to maximize total benefits. For example, suppose that an agency facing 100 evasive firms has an enforcement budget of \$100 per firm, or \$10,000, and that the optimal combined strategy sets C at \$80 and D at \$100. After several rounds, the agency notices that 40 firms are cooperating, so it has \$20 per firm (D−C), or \$800, to reallocate. The agency then sets new enforcement levels, C_1 and D_1, such that the marginal returns on enforcement are equal at (C_1,c) and (D_1,e) and the budget is fully expended, or $40xC_1 + 60xD_1 = \$10{,}000$. Given our initial assumptions, $C_1 > C$ and $D_1 > D$; as an example, this maximizing allocation might be $C_1 = \$85$ and $D_1 = 110$.

If eventually all firms cooperated, $C_n = \$100 = D$. Since the entire budget would now be used against cooperators, all firms end up facing the initial deterrence level of enforcement even though they comply at the cooperative level c. In other words, firms end up with the initial sucker payoff at (D,c), while the agency gains the initial temptation payoff! If any individual firm evaded in this new situation, it would face much more extensive enforcement actions. By reducing C_n by just one

[15] The greatest weakness is that attempts to build a reputation for ruthlessness as a basis for exploitation are likely to encounter a counteroffensive from the other player. Then the strategies in the continuous game reflect the same problem as the single period prisoner's dilemma, since either player is better off if he alone exploits the other but both players are better off cooperating (by not trying to exploit the other) than when both try to exploit. Thus, the quest for reputation introduces uncertainties that make the establishment of cooperation unlikely and is likely to produce results unsatisfactory to both sides. This quest is perhaps most applicable in the regulatory context for initial court contests in which firms challenge the legality of citations based on new regulations. The problem for the agency is similar to the chain store paradox discussed by Selten (1978).

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dollar, for example, the agency would now have $199 to bring to bear against the one evader. Nothing would prevent an agency in such an environment from repeatedly refining its modified strategy so as to demand a yet higher standard of cooperation until the highest cooperative level consonant with enforcement and evasion technologies is reached.

Unlike the initial model, only the agency gains from this dynamic. By reallocating enforcement resources in each round, the agency manipulates the payoff matrix to ensure that cooperation for the individual firm remains preferable to evasion in every round. The agency thus exploits the inability of firms to formulate a unified compliance strategy.

The assumption of independent games for each firm was initially acceptable because firms had no strong incentive to conspire against a TFT agency interested in net benefits. If we relax this assumption and allow regulated firms to conspire and jointly evade the law, the increasing number of evaders would force the agency to reduce both C_n and D_n. If all firms conspired against the exploitative agency seeking to maximize its total benefits, the initial deterrence solution would again be reached. While the firms would be better off at deterrence than at maximal exploitation, they would still prefer the reward for mutual cooperation. Thus, if they faced an agency using the combined strategy to maximize net benefits, cooperation would be likely.[16] But they have no incentive to cooperate when confronting an agency using the modified strategy, since cooperation would again lead to maximal exploitation. When a modified strategy is used against conspiring firms, the deterrence solution is the most likely outcome.

Despite the interest that conspiring firms have in joint action, the "free rider" problem confronting the conspirators means that the agency will probably be able to shift C and D to some extent in the direction it desires. Although the firms as a group are better off if all evade, every individual firm is better off complying at every stage of the exploitation process. The agency, realizing this, might seek some enforcement level for which the difference between the firm's payoff at (C_n,c) and the initial deterrence payoff at (D,e) is not quite sufficient to

[16] Conspiring firms can also exploit the agency. They can act jointly to reduce the agency's requirement for voluntary compliance by offering to cooperate at lower compliance level c′ in return for cooperative enforcement level C. As long as the agency's benefits (c′−C) are greater than at the deterrence solution (e−D), the agency is better off accepting the firm's offer provided that deterrence is the only alternative. This is most likely when an isolated, single-industry regulatory agency faces a well-organized industry, but only if the industry as a whole does not benefit from the agency's regulations.

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motivate the group to overcome the free rider problem. Thus, the agency's ability to structure a unified game against all firms compensates to some degree for the ability of firms to cheat occasionally without getting caught.

The problems of exploitation and conspiracy in enforcement arenas deserve further analysis, but just two additional observations will be made here. First, from society's point of view, this exploitative strategy may be, but is not necessarily, bad. It is socially beneficial if the initial enforcement level is suboptimal, but it is socially harmful if the initial enforcement level is at or above requirements for social optimality. Second, even if a broad-based conspiracy is possible, such flagrant noncompliance is likely to be used, if at all, only as a last resort. The sanctions for such resistance are likely to reflect the resources of the criminal justice system and be far more substantial than the penalties the agency is authorized to impose on noncomplying firms. In addition, the firms' key decision-makers may be personally liable for conspiratorial actions, and they may be more influenced by the threats of personal harm than they are by the prospect of objectively more serious penalties visited on their firms. Finally, if the conspiracy becomes well-publicized, political responses are likely to provide the enforcing agency with larger enforcement budgets and added prosecutorial authority.

D. Interest Groups and Nonpolicy Payoffs to the Agency

Most theories of regulation assume that agency behavior responds not just to policy goals but also to legal and political considerations. Theories of "capture" emphasize the importance of such nonpolicy inducements as political payoffs to the agency (e.g., budget or legislative support in Congressional committees, public support in crisis situations) in charitable analyses and personal payoffs to employees (high-paying career opportunities in industry) in less charitable ones (Mitnick, 1980; Peltzman, 1976; Quirk, 1981). Although these theories generally focus on rule-making activities rather than enforcement, our model is capable of analyzing the effects of interest groups on enforcement behavior and cooperation.[17]

Interest groups try to affect the agency through inducements or pressures that are unrelated or detrimentally related to policy payoffs. Channels of influence can act directly

[17] Note that even "captured" agencies whose regulations aid the regulated industry face the enforcement dilemma, since individual firms can benefit from evading laws even if evasion hurts the industry as a whole.

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on the agency or indirectly through legislative, executive, or judicial institutions. The model is easily adapted to such attempts at influence, for policy and nonpolicy payoffs can be combined to determine the agency's total payoff for any pair of choices by firm and agency. The relative importance of different payoffs to the agency determines the weight given to each. This expanded model can be used to analyze a range of complex environmental influences that affect the relationship between enforcer and subjects.

It is likely, for example, that a firm's political support for the agency increases as enforcement expenditures decrease. This reduces the optimal enforcement level regardless of the level of firm compliance. Thus, adding such nonpolicy benefits to Figure 2 raises each compliance option curve more on the left than on the right, which reduces the marginal return on enforcement at each point and the enforcement level at which the marginal return equals one.

If the difference in policy and nonpolicy benefits for different levels of enforcement is of the same magnitude but in opposite directions, the enforcement dilemma may disappear entirely. For example, if the difference in political support for cooperative versus deterrence enforcement levels in Figure 1 were as valuable to the agency as a reduction in pollution of 26 tons or more, the agency would do better by choosing cooperative enforcement regardless of what the firm chooses. And if the agency always chooses cooperation, the firm is better off evading and receiving the temptation payoff in each round. This perverse combination of cooperative enforcement and evasive firms is the enforcement equivalent of capture.

Of course, capture in some circumstances can work in the opposite direction. Groups that benefit from regulation may threaten to use such inducements as adverse publicity, accusations of favoritism or corruption, court challenges, and the harassment of agency officials to counter inducements from regulated firms and discourage accommodation and flexible enforcement. If nonpolicy inducements grow as enforcement becomes more stringent, the agency may always be better off with strict enforcement. The greater the bias of nonpolicy payoffs in either direction, the less likely that mutual cooperation will occur.

E. Unstable Environmental Conditions

Finally, cooperative strategies may fail to develop because environmental conditions are too much in flux to allow the

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evolutionary process envisioned in the model to reach a stable solution. Regulatory payoffs fluctuate over time with changes in political leadership, statutes, regulations, court rulings, enforcement techniques, production and compliance technologies, and in the resources available to firm and agency alike. To the extent that these changes can be represented as small, random fluctuations around base payoff values, conclusions about cooperative solutions are not necessarily affected. If firms are assumed to know only past payoffs, for example, the expected value to the firm of randomly fluctuating t, r, p, and s payoffs will converge on the expected value of the base payoff matrix. As long as the expected value supports cooperation, firms may still be expected to become increasingly cooperative over time, but the greater the variance in payoffs between periods, the slower the rate of conversion to cooperative strategies.

When environmental changes lead to nonrandom alterations of payoffs, the effect of any particular change can be analyzed by using the altered payoffs appropriate to future periods and calculating the minimal values of w required for cooperation under the new condition. The algebra will not be repeated here. As would be expected, anticipated increases in compliance costs or decreases in sanction severity and cost tradeoffs will make it more difficult to sustain cooperation. If an anticipated change is expected to make later cooperation unrewarding, cooperative strategies for the firm will become suboptimal at some (calculable) point prior to the change. Expected diminutions in the intensity of interaction between firm and agency have the same effect. Thus, anticipated changes unfavorable to cooperation reduce the likelihood of current cooperation.

Finally, economic changes are likely to affect cooperation by affecting the firm's evaluation of the future. Firms on the verge of bankruptcy, for example, care little about future rewards when considering current temptations. The low value they place on future payoffs, i.e., their low w, makes cooperation unlikely. More speculatively, since w decreases as the cost of capital increases, the model predicts that the number of cooperating firms is likely to decrease as interest rates and other factors affecting the cost of capital increase. Factors affecting the likelihood that firms reassess their strategies are also important. Scholz and Rhee (1984), for example, found that firms falling behind their peers on general performance standards are most likely to violate the law. This

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suggests that relative performance is an important determinant of changes in a firm's strategy.

VI. CONCLUSION

The model developed in this article shows that an enforcement strategy that combines cooperation and deterrence is likely to produce greater net benefits than a single-minded deterrence strategy if 1) the agency pursues a strategy with the vengefulness and forgivingness of TFT, 2) most firms' concerns about future encounters (w) are greater than the minimal cooperative value for the cooperative standards of compliance and enforcement set by the agency, and 3) the enforcement environment produces payoffs consistent with the four assumptions about compliance benefits. The advantage of the combined strategy over simple deterrence strategies increases with enforcement tradeoffs that reduce costs for cooperative firms, with diminishing returns that increase the advantages of cooperation, and with the degree to which the sanction structure favors cooperation over evasion. On the other hand, the advantage is limited by the maximum level of voluntary compliance determined by the given enforcement situation and by the firms' concern with the future.

Actual cooperation may fall short of what is potentially obtainable because of factors that limit cooperation in the real world. The diversity of firms in an enforcement arena, insensitivity to the virtues of the combined strategy, and uncertainty in identifying evaders all detract from an agency's ability to elicit cooperation. Firms, on the other hand, may fail to respond to the combined strategy because they fail to recognize the advantages of cooperation. Crusading agencies confronting conspiring firms can also destroy mutually beneficial cooperation or prevent it from emerging. Interest groups offering nonpolicy inducements can alter agency payoffs sufficiently to change the nature of the enforcement dilemma and eliminate the agency's incentive to seek cooperation or the firm's incentive to comply. Institutional instability and anticipated changes can have a similar effect. Conversely, cooperation can be increased if these obstacles can be pruned or eliminated.

Although this article looks primarily at regulatory cooperation, the evolutionary game theory model offers several conceptual additions to deterrence theory that can be applied to other enforcement problems as well. First, the model's focus

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on simultaneous, continuous, and contingent choices by enforcer and subject comes closer than the focus on sanction certainty and severity that characterizes deterrence theory to the strategic concerns noted in interviews with firm and agency officials alike (Bardach and Kagan, 1982; Hawkins, 1984; Carson, 1970). Each set of officials is well aware of the impact that current decisions are likely to have on the other's future behavior. Deterrence theory generally analyzes only equilibrium outcomes of the long-term game, and therefore misses important details about short-term strategic requirements (like the important role of forgivingness in the TFT strategy) that are a part of conventional enforcement wisdom.

Second, the perspective of the enforcement arena as an ecology of enforcement and evasion strategies allows for a dynamic analysis of the evolution of relationships between firm and agency. While the static analysis of "optimal" strategies is sufficient for some problems, dynamic approaches are needed if we are to understand such phenomena as the time required to adopt new strategies after significant environmental changes, the spread of evasive strategies among firms, and the retention of suboptimal strategies due to limited learning. If parameter values for the probabilities of reevaluation, correct perception, and correct choice are specified, an extended model could predict trends to be tested against empirical observations.

Third, the effects of institutions that are only tangentially involved in the agency-firm relationship, such as courts, legislatures, political leaders, and prosecutors, are included in the model through their effects on payoffs. The model as currently formulated does not allow firms and agencies to alter the behavior of these external institutions, but a more complex model could be developed that does allow for this.

The model is offered as a promising approach to the problems of regulatory enforcement. It no doubt requires a range of normative, behavioral, and conceptual refinements if it is to contribute maximally to a general theory of enforcement and compliance. Normatively, the model's implications need to be developed for the design of regulatory and enforcement policies. We have seen with the aid of our model that the combined cooperative and deterrence strategy can correct some of the inefficiencies associated with rule-oriented "command and control" approaches to regulation. Furthermore, the model explicitly relates expected compliance benefits to the frequently neglected enforcement costs and

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incentives that are faced by firms and agencies. Thus, the model provides a broader basis for analyzing in particular settings the optimal level for setting standards that take account of imperfect compliance (Viscusi and Zeckhauser, 1979), the choice between performance and specification standards, and the issues that arise when command and control approaches are contrasted with market-oriented regulatory approaches (Schultze, 1977; Poole, 1982). The model can be used to evaluate proposed changes in sanctions, agency organization, and enforcement budgets and techniques. Such analyses should focus on the specific circumstances of particular regulatory arenas. This will allow more realistic assumptions about compliance benefits, sanctions, cost tradeoffs, and diminishing returns of the marginal compliance investment.

Behaviorally, the model requires systematic empirical testing in a range of enforcement environments to establish its utility in predicting agency and firm behavior. For example, the model predicts that an agency's strategy towards different major industries depends on payoffs and firm types in each industry. This prediction should be testable by using the model to predict differences in enforcement records on the basis of differences in payoff structures. The difference between evasive and cooperative firms in each industry is, according to the model, dependent on specific differences in payoffs, future discount parameters, and probabilities of reevaluation. This too can be tested. Case studies relating firm behavior to the strategic patterns (like TFT) and limitations highlighted by the model will also help establish the utility of the model. Empirical investigations can also extend the model by clarifying the frequency of various parameter values and generating data on the behavioral implications of specific values.

Conceptually, several alternative game theory approaches could be incorporated to increase the model's utility. The reliance on discrete time periods in the model makes the analysis more tractable, but a translation of the vengefulness and forgivingness characteristics into a continuous time model would be analytically more attractive and might be more revealing of subtleties than the current analysis. Another important extension is to analyze independently the strategic requirements of the prosecution game that commences only after evasion is detected in the initial monitoring game. The effects of continued uncertainty about the firm's compliance

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choice merit further consideration, as does the special case of enforcing a new regulation, where a tough agency reputation may play a critical role in encouraging initial compliance.

Finally and perhaps most importantly, the model might be extended to consider the role of normative commitments to obey laws in the evolution of cooperation. By specifying how this community-oriented component of utility evolves and interacts with egoistic cooperation, dynamic interrelationships between egoistic and normative cooperation could be studied empirically in environments with declining or increasing incentives for egoistic cooperation. The basic framework of analysis presented in this article provides sufficient scope for viewing this and other hitherto separate compliance and enforcement concerns from a more unified perspective.

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