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ENFORCING TIME INCONSISTENT GOVERNMENT REGULATIONS

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ABSTRACT

Certain government regulations require a good deal of investment by firms before the regulations actually go into effect. In these cases, if a firm does not engage in the desired level of investment, it can be quite costly to society to actually enforce the regulation. This paper derives a game theoretic model of how such regulation could be enforced by examining the bureaucratic incentives of the various governmental parties involved in overseeing a regulatory program.

I. Introduction

Business firms are required to deal with a number of regulations. In changing their behavior in reaction to government directives, firms must take a number of factors into consideration. Regulations may require them to invest in certain processes and facilities in order to meet the government's mandates. Firms, however, also know that the government cannot legally bind itself to future actions. Thus, when considering its own actions in response to regulation, a firm will consider the possibility that the government will later choose not to enforce its mandate. The firm may also take into its decision function that its own actions may affect whether or not the government later chooses to enforce its earlier policy directive.

Examples of such standards are regulations on automobile fuel economy levels or automobile pollution emissions. Congress passes a law that sets a standard for a year several years in advance of that year occurring. Firms then engage in innovation prior to that year in order to be able to meet the standard. Firms, however, can always go back to the regulatory agency or Congress immediately prior to the year in question and ask for relief from a certain standard. The agency or Congress then decides whether or not to change the standard, and one of the factors assessed in making the decision is how much successful investment the firm has already made. After the government has made its decision the firm then engages in short-term product changes in order to meet the standard.

In the case of government regulation of automobile fuel economy standards, Congress in 1975 set fuel economy standards for years 1978 and afterwards, leaving the executive branch some administrative discretion.

Firm underwent long term product investment in order to meet the standards. In 1984 and 1985, however, automobile firms petitioned the government for regulatory relief for the following model years. The government eventually did grant relief, but not until the actual start of the model years in question. If relief had not been granted, there would have been no time left for product innovation and firms would have had to meet the standard with the higher cost strategy of restricting the mix of their product output.

In both the cases of automobile fuel economy and pollution it would seem far cheaper for the standard to be reached by investment that takes place before the period in question occurs. The government threatens to enforce the standard even if the proper amount of investment has not taken place. Once this point is reached, however, it may be in the government's best interest to relax the standard and avoid the high costs to society of meeting that standard given the small amount of previous investment. What would seem to occur here is the standard Nash equilibrium, where given that the government will enforce the standard, an automobile firm will undertake the desired level of investment. If, however, the firm undertakes less than that level of investment, it may not pay for the government to force the firm (and perhaps society in general) to undergo the costs involved of meeting the standard. Given that the game is of finite length, the government will never enforce the standard if the investment is not undertaken. The firm will understand this, and thus undertake no investment in meeting the standard. The government will thus be unable to enforce the regulation.

This conclusion, while logical, is apparently untrue. For example, in the 1970's the government did pass laws requiring automobile companies to invest millions of dollars in pollution control devices. While the auto firms complained loudly and achieved some delay in the implementation of the law, in the end control devices were installed. (See White (1981).)

A body of literature (for example Baron and Besanko (1984, 1987) and Yao (1985)) have dealt with the notion of incentives and regulation. In these papers, the government sets some regulatory standard and the firm(s) in question maximize their profits subject to that regulation. A crucial assumption of these papers is that the government is able to precommit to making its regulations stick, that is make the firm believe that some event which will be costly to the firm will occur if the firm does not meet the regulatory standard set in place by the government.

This problem becomes especially acute when meeting the regulation involves certain types of investments that must be made prior to the period in which the regulation is going to be enforced. In these instances, enforcing the regulation if large amounts of prior investment are not made can be quite costly. While the government may threaten to enforce the regulation even if the investments are not made, it may find that enforcement in that case is much too expensive. Such a standard may be considered "time inconsistent" as the government may not be able to credibly commit itself to enforcing the regulation.

The goal of this paper is to derive a game theoretic model which demonstrates how a government might be able to enforce such regulations. The papers cited above made assumptions of assymetric information, with the firm having uncertain cost characteristics. This paper will reverse the situation, assuming that the firm's cost functions are known while the government's response is uncertain. Unlike the above cited papers, this article will assume that at least part of the government is interested in maximizing its own, rather than the public welfare. Because firms realize that the government might act in its own interest against the public welfare, the government may be able to enforce its regulation.

II. The Regulatory Institutions

Let us say that a legislature passes a bill, setting a regulatory standard at S. The bill, however, generally gives the executive branch authority to lower the standard should some unforeseen event occur. Alternatively the bill can be thought of as giving the executive the power to set a regulatory standard up to S. The bill then goes to the executive for his approval.

The bill sets up a bureau to oversee and enforce that standard, and the legislature gives oversight and/or budgetary authority to the committee that originated the bill establishing the standard. Consider the incentives of the regulatory bureau. If its goal is to maximize its prestige and budget, as Niskanen (1971) suggests, then it will try to keep its oversight committee happy by always enforcing the standard. If it does not enforce the standard, it is then forced to tell the committee its reasons for not doing so. This can a quite uncomfortable event for the bureau's administrator. Further, the committee may be willing to reduce the bureau's funding if the standard is not enforced. Thus, it is assumed here that the bureau always prefers to enforce the standard.

It would appear quite likely that this oversight will be done by what Niskanen calls a "high demand" committee. What is meant by "high demand" is that the members of the committee have a greater desire for the government good in question than the entire legislature. Weingast and Moran (1983) come to a similar conclusion when analyzing memberships in such committees. For instance, one would not expect to see a congressman from Iowa or Nebraska on the Merchant Marine and Fisheries Committee. In the case of regulatory standards, legislators could have gotten themselves placed on the relevant committee because they were interested in the first place in establishing the standards.

Furthermore, once the standards are in place, these congressman have a sunk cost in their enforcement, since they are the ones who argued for them in the first place. Thus, they will be stronger supporters of the standards once they have been passed than the average legislator. Once the bureau is established, it is not easily eliminated. Only rarely does the government eliminate an agency. (The Civil Aeronautics Board would appear to be the exception to this rule.)

The executive, however, has a different viewpoint. He presumably acts by considering the welfare of the whole country when making his decision. Thus, he may want to intervene and set a new standard if the proper investment has not taken place. Unfortunately for the executive, he only has limited power over the bureau. In fact, legally his only power may be to hire and fire the administrator of the bureau. Further, being the executive is often quite a difficult task. Faced with his other burdens, the executive simply may not be able to influence his appointee into adjusting the standards. The regulated firm does not know if the executive is "strong" or "dominant" (type=Y) and can intervene and grant regulatory relief or if he is "weak" and cannot (type=N). Given the other actions of the executive, however, the firm knows that there exists a probability p^Y, $0<p^Y<1$ that the executive is strong. The firm will thus minimize its regulatory costs given that probability and the previous events in the game. It is assumed that p^Y cannot be changed by any action of the firm.

III. The Regulatory Game

The game analyzed here has two periods, i=1,2. Each period has three stages. In the first stage of period i of the game the firm improves the regulatred aspect of its product F_i, moving towards reaching the towards reaching the regulatory standard with cost $g(F_i)$. The firm choose F_1 to minimize the present value of its expected costs over the two period game, given p^Y. In the second stage the regulatory bureau sets the standard S_i, which may or may not be equal to the mandated standard S. In the third stage the firm has no choice but to improve its product $H_i=S_i-F_i$ at cost $j(H_i)$ in order to reach the standard. An outline of the game is laid out in Figure 1.

For simplicity the cost functions will be assumed to be

$$(3\text{-}1)\ g(F_i) = aF_i^2$$

$$(3\text{-}2)\ j(H_i) = bH_i^2$$

with in general b>a. Total cost to the firm in period i is thus

$$(3\text{-}3)\ C_i = aF_i^2 + bH_i^2$$

The firm is assumed to gain no benefit from the production of this good and hence without regulation it would not be produced. The firm is also assumed to be risk neutral.

Society is assumed to value the regulated good with constant marginal utility v. Dropping subscripts, the net total social welfare from reaching a level of the regulated good $S = F + H$, of which F is generated from first stage investment and H is the third stage investment, is

$$(3\text{-}4)\ W = vS - C = v(F+H) - aF^2 - bH^2$$

Using derivatives to solve for F^* and H^*, the values of F and H that maximize social welfare yields

$$(3\text{-}5)\ F^* = v/2a$$

$$(3\text{-}6)\ H^* = v/2b$$

and S^* is set

$$(3\text{-}7)\ S^* = F^* + H^* = v(a+b)/2ab$$

Both methods of innovation (in the first stage and in the third stage) are desired to be used until their marginal cost is equal to v. Since the two production functions are independent F^* and H^* will both be greater than zero if v is greater than zero. It is assumed that the legislature sets the optimal standard $S^*=S_1=S_2$ in the bill establishing the standard. It is also assumed that the government cannot observe F_i prior to the second stage of period i.

The firm has an initial probability p^Y that the executive is of strong type. The firm updates its probability during the game according to Bayes' Law. If the executive is of strong type, it sets the standard to maximize net welfare, knowing that the firm will take a new standard in period 1 into account when making its investment in period 2. The firm's strategy in each period is to set F_i so as to minimize its costs (maximize its profits). The executive sets S_i to maximize net welfare. A sequential equilibrium to this game will be solved using backwards induction.

Second Period: Third Stage

At this stage the firm has already made its first stage product improvement F_2 and the government has set a standard S_2. The firm has no choice but to improve its product $H_2 = S_2 - F_2$.

Second Period: Second Stage

If the executive is of type N, he is unable to overrule the bureau's decisions and the bureau sets $S_2=S^*$. If the executive is of type Y he intervenes. Facing previous investment in the first stage F_2 he maximizes over S_2

$$(3\text{-}8)\ W = vS_2 - aF_2^2 - b(S_2-F_2)^2$$

Taking derivatives and setting equal to zero yields

$$(3\text{-}9)\ dW/dS = v - 2b(S_2\text{-}F_2) = 0$$

or

$$(3\text{-}10)\ S_2\text{-}F_2 = v/2b = H_2 = H^*$$

Note that the value of H_2 is not dependent on the level of first stage improvement F_2. This implies that if the firm knows that the executive is of type Y, he has no incentive to undergo first stage improvements.

Second Period: First Stage

The goal of the regulated firm at this point is to minimize its expected costs over the probability that the executive is of type Y. That probability, p_2, is a function of p^Y, the a priori probability that the executive is of type Y, and the events of the first period. If the executive did intervene in period one the firm knows with probability 1 that the executive is of type Y. Therefore, p_2, the probability of the executive intervening in period 2 is

$$(3\text{-}11)\ p_2 = 1$$

if intervention occurred in period one and

$$(3\text{-}12)\ p_2 = p_2(p^Y, F_1, S_1) = p_2(p^Y, F_1)$$

if intervention did not occur. (S_1 equals S^* if intervention did not occur.) The firm thus knows that given its first stage improvements F_2 it will have to improve its good H^* with probability p_2 and face probability $1-p_2$ that its good will have to be improved S^*-F_2. Given this, the firm thus minimizes its expected costs over F^2,

$$(3\text{-}13)\ \text{Min } E(C_2) = p_2(aF_2^2 + bH^{*2}) + (1-p_2)(aF_2^2 + b(S^2 - F_2)^2)$$

Taking the derivative of (3-13) with respect to F_2 and setting it equal to zero yields

$$(3\text{-}14)\ dE(C)/dF_2 = 2aF_2 - 2(1-p_2)\ b\ (S^*-F_2)=0$$

Solving for F_2:

$$(3\text{-}15)\ F_2 = (1-p_2)bS^*/[a+(1-p_2)b]$$

Substituting in for S^* yields

$$(3\text{-}16)\ F_2 = F^*(a+b)(1-p_2)/[a+b(1-p_2)] = F^*k(p_2)$$

The function k is the fraction of optimal investment undertaken by the firm given the firm's conditional probability that the executive is Type Y (strong). Note that $k(1)=0$, $k(0)=1$ and $dk/dp_2<0$. Thus, if the firm is certain that the executive is of type Y it will not undergo any first stage improvements in the good in the second period. Conversely, if the firm is certain that the executive is of type N then it will undertake the socially optimal amount of first stage improvements.

First Period: Third Stage

The firm now faces a standard S_1 and has made first stage improvements F_1 (As shown above, S_1 will either equal S^* or F_1+H^*). The firm has no choice but improve its product S_1-F_1.

First Period: Second Stage

If the executive is of type N then the standard will be set at S^*. If the executive is of type Y, then he will grant relief (setting the standard at $F_1+H^*(<S^*)$ if the benefits of doing so outweigh the costs.

The benefits from relief occur in the first period, as the reduced cost from the lower standard $b(S^*-F_1)^2-bH^{*2}$ is greater than the loss from the lower standard $v(S^*-H^*+F_1)$ if $F_1<F^*$.

$$\text{(3-17) Benefit of Relief} = B^Y(F_1) = [b(S^*-F_1)^2 - bH^{*2}] - [v(S^*-(H^*+F_1))]$$

Note that $dB^Y/dF_1<0$ if $F_1<F^*$. Thus, the lower the investment in the first stage, the more there is to be gained from granting relief.

The cost of granting relief occurs in the second period. Since the granting of relief demonstrates that the executive is of type Y, (3-15) implies that if relief is granted in period one the firm will undergo no product improvement in the first stage of period two. Let $p^m=p_2(p^Y, F_1$, No relief). Since these costs are one period later than the benefits noted above, they are discounted by a government discount factor R^g, $0<R^g<1$. The government may or may not value the future at the same rate as a private firm. For instance, if an election is imminent, the executive may be much more concerned about satisfying voters today than voters tomorrow. The costs to the executive of granting relief, C^Y, are

$$(3\text{-}18)\quad C^Y(p^m) = R^g[v(F^*k(p^m) - F^*k(1)] - R^g[a(F^*k(p^m))^2 - a(F^*k(1))] = R^g[vF^*k(p^m) - a(F^*k(p^m))^2]$$

Note that $dC^Y/dp^m<0$. Thus, the greater the expected probability that the executive is of type Y after relief is denied, the greater the costs of granting relief. Setting (3-17) equal to (3-18) and solving for F_1 yields the point for which the executive is indifferent as to whether or not to show itself as type Y and grant relief, given p^m.

Let F^n be the indifference point for the executive between granting relief and not granting relief given that $p^m=p^Y$ (that is, the firm is not fooled by the standard being enforced, since the firm believes that given the level of F_1 if the executive was of type Y, he would not have granted relief and therefore exposed himself as type Y.)

Solving for F^n yields a quadratic, F^* plus or minus a constant. Since F_1 is never greater than F^*, the larger of the solutions for F^n can be disregarded and

$$(3\text{-}19)\quad F^n = F^* - (Q(p^Y)/b)^{.5}$$

where $Q(p^Y)$ equals

$$(3\text{-}20)\ Q(p^Y) = C(p^Y) + bF^* + bH^* - bS^* + vF^*$$

Define Region III as $[F^n, F^*]$. By definition if F_1 is in Region III, the executive will prefer not to grant relief, since the costs of granting relief are greater than the benefits. If relief is not granted when F_1 is in Region III, the firm has no reason to believe $p_2 > p^Y$. Thus, if F_1 is in Region III, it always is optimal for the executive if he is of type Y to "duck" the issue and not grant relief. Thus, it is conceivable that a pooling equilibrium could occur, as in this region the result in period one is the same no matter what type the executive is.

Assume that if relief is not granted the firm believes that the executive is of type N. Setting (3-17) equal to (3-18) with $p^m = 0$ yields $F^Y < F^N$ (if $p^Y > 0$).

$$(3\text{-}21)\ F^Y = F^* - (Q(0)/b)^{.5}$$

Define Region I as $[0, F^Y]$. Since p_2 cannot be less than zero, this implies that if F_1 is in Region I, a type Y executive will always grant relief. The benefits of granting relief are always greater than the costs, even though if relief is not granted the firm believes with probability one that the executive is of type N (weak).

Define Region II as $[F^Y, F^N]$. If F_1 is in this region there is no pure strategy equilibrium for the executive. The proof goes as follows: Take any point F_1 in Region II. If the executive's strategy is to "duck" and not grant relief, then $p_2 = p^Y$, as the firm knows that the type Y executive will try to mimic the type N executive. If, however, $p_2 = p^Y$, then by the definition of Region II it is optimal for the type Y executive to grant relief. In that case, however, $p_2 = 0$. No pure strategy is an equilibrium for the type Y executive because once he adopts that strategy the firm will have expectations in period two that make the strategy non-optimal.

While there is no pure strategy solution in Region II, there is a mixed strategy solution. Define p^M as the value of $p_2(F_1)$ for each value of F_1 such that the cost of relief for a type Y executive is equal to the benefits of relief. As shown above, $p^M(F^Y)=0$ and $p^M(F^N)=p^Y$. The derivatives of the costs with respect to p^M, dC^Y/dp^M, is <0 and $dB^Y/dF_1<0$. Since the cost of granting relief equals the benefits by the definition of p^M, it implies that $p^M/dF_1<0$ and $0<p^M(F_1)< p^Y$ if F_1 is in Region II. Solving for k yields

$$(3\text{-}22)\quad k= 1- (1-(4aB(F_1)/v^2R^g)^{.5}))$$

where p^M equals

$$(3\text{-}23)\quad p^M= ((a+b)(1-k))/(b(1-k)+a)$$

Assume that if F_1 is in Region II the type Y executive adopts a mixed strategy, granting relief with probability $L(p^M, p^Y) = (p^Y-p^M)/[p^Y(1-p^M)]$. The firm then believes that if relief is not granted the executive has a p^M chance of being of type Y, as it updates its beliefs according to Bayes' Law.

Note that $L(0, p^Y)=1$ and $L(p^Y, p^Y)=0$. Thus, the firm has no incentive to switch out of this strategy and an equilibrium is reached.

While a mixed strategy is the logically correct solution for Region II, it is not clear what it means in this context. A mixed strategy implies that before the game starts, the executive is able to commit himself to granting or not granting relief at random should a Region II outcome occur. Thus, while the firm does not know what type the executive is, it does know that a type Y executive will have already committed himself to a mixed strategy. This may not be a realistic assumption, but given the absence of any other type of equilibrium, it will be made in the rest of this paper.

First Period: First Stage

Given the strategies calculated above, the firm now attempts to minimize its expected costs by choosing F_1. If it chooses F_1 in Region III it knows that relief will be granted with probability 0 (the standard will be enforced with probability 1). If it chooses F_1 in Region II it knows relief will be granted probability $p^Y L(p^m(F_1), p^Y)$. If it chooses F_1 in Region I it knows relief will occur with probability p^Y. The firm thus faces the possibility frontier outlined in Figure 2.

A solution to the firm's cost minimization problem can be generated by analyzing the lowest cost strategy for each of the three regions. Assume that the standard will be enforced with probability $1-p^Y$. The firm will thus minimize its expected costs

$$(3\text{-}24)\ \text{Min } E(C(F_1)) = (1-p^Y)[aF_1^2 + b(S^*-F_1)^2] + p^Y(aF_1^2 + bH^{*2}) + R[(1-p^Y)(aF^{*2}+bH^{*2}) + p^Y bH^{*2}]$$

where R is the private or market discount rate. Solving for F_1 yields

$$(3\text{-}25)\ F_1 = F^*k(p^Y) = F^I$$

F^I can be in any of the three regions. If F^I is in Region I, that is the minimum cost point for the firm. The proof is as follows: Given that the probability of relief being granted is p^Y, the firm will prefers F^I over all other points in Region I. Take any F_1 in Regions II or III. The probability of relief being granted at any such investment F_1 is less than p^Y. Since $dE(C(F_1))/dp < 0$, such a point has higher costs associated with it then if it had probability of relief p^Y. By the definition of F^I, however, even were the probability of relief p^Y at an F_1 in Regions II and III, the firm would still have lower expected costs at F^I. Thus, the firm will choose F^I over any F_1 in Regions II or III.

The situation is more complicated if F^I lies in Regions II or III. In that case, $dE(C(F_1)/dF_1>0$ for all F_1 in Region I and the firm prefers F^Y to any other point in Region I.

Assume that the standard will always be enforced. Then the lowest cost strategy for the firm is $F_1=F^*k(0)=F^*$. Thus, for all points in Region III, the lowest cost strategy is F^*.

It can be shown with some difficulty that there is no minimum cost point in the interior of Region II. The outline of the proof is as follows:

The shape of the possibility frontier in Region II is an oval, which implies the derivative of expected costs with respect to F_1 at F^Y is positive infinity. It also implies that dp/dF_1 at F^N is zero, and thus the derivative of expected costs at that point is positive (this comes from the analysis of all points in Region I). Thus, the point in Region II where the cost derivative equals zero is a cost-maximizing point. The two candidates for cost minimizing points in Region II are F^Y and F^N. But since F^Y is in Region I it is weakly dominated from the firm's point of view by F^I. Since F^N is in Region III and not equal to F^* it is dominated by F^*.

Thus, if F^I is greater than F^Y, the firm will choose between F^Y and F^*. This implies that the firm will either choose to meet the standard, or miss it by at great deal. It also implies that if the firm does not choose to meet the standard it will pick a F_1 low enough so that a Type Y executive will always grant relief. The firm will not allow a pooling equilibrium to exist if it decides not to meet the initial part of the standard.

While this model has only one firm, its results can be extended to an industry with many identical firms. It can be shown that regulations such as these can be easier to enforce if there are many firms in the affected industry only if these firms have different cost structures and hence different F^Is. Intuitively, this is because the nature of the regulatory possibility frontier (as in Figure I) faced by firms is not markedly different in a competitive industry than that faced by a monopolist.

IV. Numerical Rèsults

The results of the previous section imply that there is a certain cut-off point for which the regulation will be met. That is, if the probability that the executive is of type Y is sufficiently low the firms will act to meet the standard in period 1. The results in Table 2 indicate that p^Y must be at a fairly low level for the policy to be upheld. Put another way, to enforce a time inconsistent regulation implies that there is a good probability that the bureau, not the executive, is setting policy.

Table 2 generates the maximum p^Y allowable for the policy to be enforced. The coefficient of first period costs, a, is set at 1 as the numeraire. The marginal utility of the regulated good is set at 1 in the computer program, although the results are invariate with respect to it. The private discount rate, R, equals .96.

Not surprisingly, Table 1 shows that the higher the discount rate of the government, the harder it is to enforce the regulation. Reducing R^g by 20 percent (from .960 to .768) reduces the maximum p^y from .545 to .484. Similar results are seen for all points represented in the table.

Increasing the factor of third stage costs b has two effects on the viability of the regulation. Higher third stage costs raise the costs to firm of not meeting the standard in the first stage. These higher costs, however, also make it more painful for the government to enforce the standard should the level of first period investment be suboptimal.

The results show that as B increases from 1 to 6 the maximum p^Y for R^g=.96 decreases from .545 to .426. For this region, the additional costs to the government have a larger effect than the additional costs to the firm. As B rises past 6, though, p^Y declines slightly.

V. Conclusion

Enforcing time inconsistent regulatory standards in the model presented has been shown to be a very difficult task. For such policies to be followed by the affected firms there must be a large probability that the regulatory bureau, and not the executive, is the agent setting policies. In the numerical examples listed the maximum likelihood that the executive is actually setting the policy never rises greatly above one half. This implies that for time inconsistent policies to be effective, a large degree of decision making power in the executive branch of government must lie with the regulatory bureau and not the chief executive. This implies that for time inconsistent policies to be effective, government may need to be less "reasonable" in order to precommit itself.

It has also been shown that if a firm is not going to meet the initial part of a regulatory it will miss it by a great deal in order to force the executive into granting relief. There is no point in missing the standard by a small amount, as in that case even a strong type executive will enforce the standard. This also implies that there is no pooling equilibrium if the firm chooses not to make the optimal amount of first stage investment. As the game is laid out, a firm will not reach the optimal first stage level of regulatory investment if the ex ante probability of that executive being strong is above a certain cut-off level. In Table 2 that level was only once above .50.

Table 1
List of Definitions of Terms

a	Coefficient of cost in g( ), a>0
b	Coefficient of cost in j( ), b>0
$B^Y(F_i)$	Benefit from granting relief in period 1.
C_i	Total cost to the firm of improvements in period i.
$C^Y(p^Y)$	Cost of granting relief in period 1.
F^*	Optimal level of first stage improvement
F_i	First stage improvements in period i.
F^I	Cost minimizing point for F_i for firm, given that relief will be granted with probability p^Y.
F^{II}	Cost minimizing point for firm in Region II (mixed strategy region).
F^{III}	Cost minimizing point for firm given that executive will grant relief with probability 0.
F^N	Minimum F_i such that the executive will want to grant relief, given that if relief is not granted the firm will have $p_2=p^Y$.
F^Y	Minimum F_i such that the executive will want to grant relief, given that if relief is not granted the firm will have $p_2=0$.
$g(F_i)$	Cost to firm of improvements F_i.
H^*	Optimal level of third stage improvement
H_i	Third stage improvements in period i.
$j(H_i)$	Cost of third stage improvements H_i
k(p)	A function of p, k(0)=1 and k(1)=0.

Table 1 (cont'd)

$L(p^m(F_i),p^Y)$	Probability that executive will grant relief, given the firm is of type Y and F_i is in Region II.
p_2	Probability that executive is of type Y in period 2, given the events of period 1.
p^M	Ex post probability p_2 for F_i in Region II such that executive is indifferent to granting relief in period 1.
p^Y	Probability that executive is strong type Y
R	Discount rate for the firm, $0<R<1$
R^g	Discount rate for the government, $0<R^g<0$
Region I	Region for F_1 such that relief is granted with probability p^Y
Region II	Region for F_1 such that Type Y executive implements mixed strategy for granting relief
Region III	Region for F_1 such that relief is never granted
S^*	Optimal level of total improvement in one period.
S_i	Regulatory standard set in period i.
v	Marginal and average value of regulatory improvements
W	Net welfare of regulatory policy

Table 2

Maximum P^Y That Enforces Standard

A=1, D=1, R=.96

		Government Discount Rate R^g				
		.960	.768	.576	.384	.192
	1.0	.545	.484	.411	.320	.200
	2.0	.466	.414	.351	.273	.168
	3.0	.443	.393	.333	.258	.159
Factor	4.0	.433	.384	.326	.252	.154
of 3rd	5.0	.428	.380	.322	.249	.152
Stage	6.0	.426	.379	.321	.248	.151
Costs(B)	7.0	.426	.378	.320	.247	.150
	8.0	.425	.378	.320	.247	.150
	9.0	.425	.378	.320	.247	.150
	10.0	.426	.379	.321	.247	.149

FIGURE ONE

Description of Stages of Game

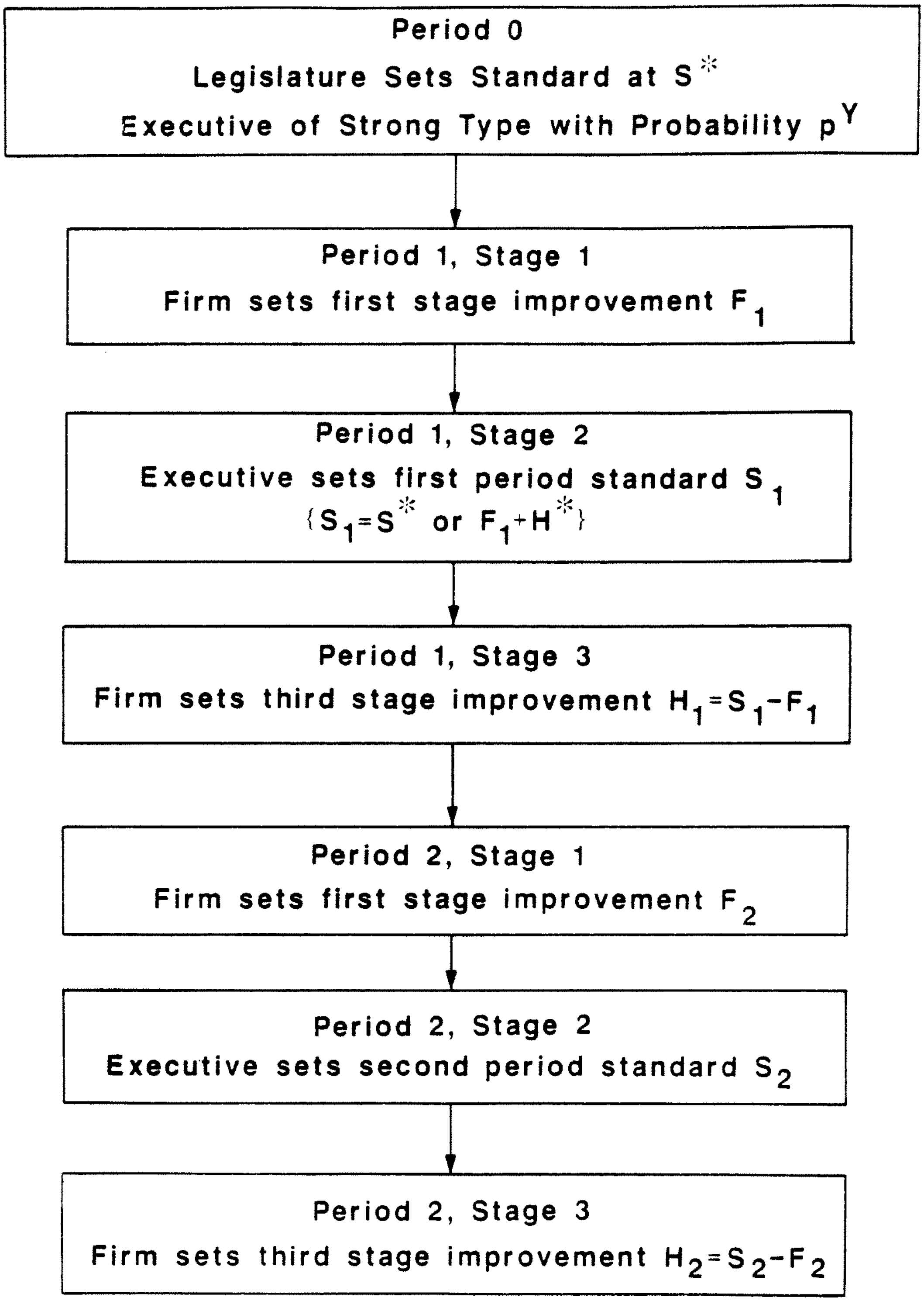
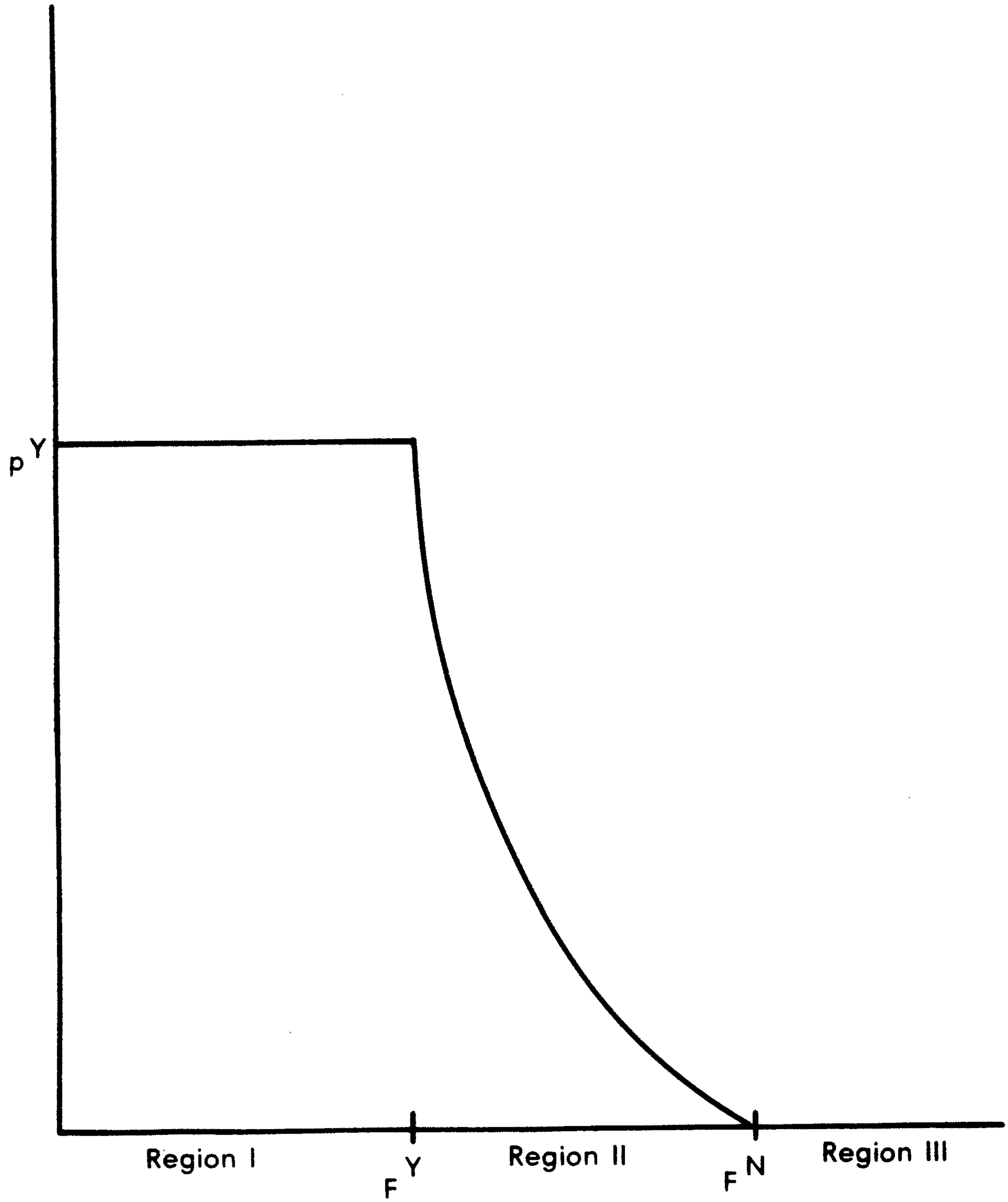


FIGURE TWO

Possibiltiy Frontier Faced

By Firm In 1st Period, 1st Stage



Level of 1st Stage Investment F_1

REFERENCES

Baron, D.P. and Besanko, D., "Regulation and Information in a Continuing Relationship," Information Economics and Policy, Vol. 1 (1984) pp.267-302.

Niskanen, W., Bureaucracy and Representative Government, Chicago: Aldine-Atherton, 1971.

Sappington, D. "Optimal Regulation of Research and Development Under Perfect Information," Bell Journal of Economics, Vol. 13 (Autumn 1982), pp.354-368.

Weingast, B. and Moran, M., "Bureaucratic Discretion or Congressional Control? Regulatory Policy Making by the Federal Trade Commission," Journal of Political Economy, Vol. 91, no.5, pp.765-800.

White, L., The Regulation of Air Pollution Emissions from Motor Vehicles, Washington, D.C., American Enterprise Institute (1981)

Yao D., "Strategic Responses to Automobile Emission Control: A Game-Theoretic Analysis," Center for the Study of Organizational Innovation, University of Pennsylvania, Discussion Paper #188, October 1985. Forthcoming in Journal of Environmental Economics and Management.