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MODELING THE CHOICE BETWEEN REGULATION AND LIABILITY IN TERMS OF SOCIAL WELFARE[1]

by

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Abstract

Using a formal political economy model with incomplete information regarding the accident preventing activities chosen by the firm (moral hazard) under limited liability, we illustrate different conditions under which an environmental protection system based on extending liability to private financiers or to insurers through compulsory full insurance of the firm is welfare superior, inferior or equivalent to a system based on an incentive regulatory scheme subject to capture by the regulatees. We consider explicitly the following factors: the differential cost between low and high levels of environmental protection activities and the associated accident probabilities, the social cost of public funds, the informational rent of the firm, the net profitability of the risky activities, the level of damages if an accident occurs, the bias factor in case of regulatory capture. We characterize in this parameter space the regions where one system dominates the other.

Keywords: Environment, extended liability, CERCLA, capture, choice of instruments.

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1 INTRODUCTION

The increasing importance of better understanding the choice between environmental policy instruments in a political economy context comes from different sources: the increasing diffusion of risky activities in modern industrial societies, the necessity to properly compensate the victims of accidents, the need to induce an efficient level of care by the potential injurers, and the increasingly stringent budgetary limits of cash-constrained governments.[1]

The choice of instruments deals in general with the ex ante policies on the one hand that regulate the risky activities of firms before an accident occurs such as safety standards, Pigouvian taxes, marketable permits, and the ex post policies on the other hand that control the effect of an accident and provide a set of rules to be applied once an accident has occurred such as emergency civil protection plans and liability systems for clean-up costs and for the compensation of victims. The two types of policies provide different incentives for precautionary care and involve different costs.

We compare in this paper two broad stylized instruments. First, an assignment of strict liability as defined in the U.S. through CERCLA[2] and in the E.C. through the White Paper[3] and second, a system of regulation rules and procedures enacted by an environmental protection authority that can be subject to capture by the regulated firms. To compare these two kinds of instruments many features must be examined: the level of administrative expenses, the magnitude of the damages in case of accident, the private knowledge of the parties regarding the causal factors of accident probability and finally the risk of capture or collusion.

The term "administrative expenses" in the case of a liability system refers to the cost of optimal control of the probability of accidents, the legal expenses and the public expenses for maintaining legal institutions; in the case of a regulation system it refers to the public costs of maintaining

[1] See for instance Menell (1991), Lewis (1996) and Segerson (1996).

[2] The *Comprehensive Environmental Response, Compensation and Liability Act* of 1980, 1985, 1996. See Pitchford (1995 and 2001), Boyer and Laffont (1996 and 1997), Boyer and Porrini (2001), Boyd and Ingberman (1997), Lewis and Sappington (1999 and 2001), Balkenberg (2001).

[3] The *White Paper on Environmental Liability* of February 2000.

the regulatory agencies and the private costs of compliance. One advantage of the liability system is that a significant part of the administrative costs is incurred only if a suit occurs while the administrative costs of a regulation system are incurred whether or not the harm occurs because the process of regulation is costly by itself.

The second element of the comparison refers to the magnitude of damages and to the party responsible for paying the clean-up and compensation costs of an accident. In a regulation system, the damages are usually directly or indirectly covered by the public parties when due care was exercised by the firms according to the standards defined by the regulatory agency. In a liability regime, the damage costs are imposed on the responsible private parties, if and when a suit occurs, given their capacity to pay and their limited liability.[4] Both systems may require some form of insurance: either a public fund in the case of the regulation system or a private insurance contract in the case of a liability system.

A third element of the comparison is the distribution of knowledge and information among parties regarding the benefits of the firm's activities, the cost of reducing risks and the probability and the severity distribution of accidents. A liability system has the advantage of making the private parties residual claimants of the control of risks when the nature of the activities carried out by the firms is such that the private parties have better knowledge of the benefits and costs of reducing risks. But, in other cases, the regulation authority can have better knowledge of those risks because of the possibility of centralizing information and decisions, in particular when a better knowledge of the risk factors requires a special expertise to be acquired through different cases and situations and shared among many parties.

A fourth relevant feature in the comparison is the possibility of capture and collusion. Both the regulatory agencies and the courts may be influenced by external pressure by interested parties. But it seems reasonable to consider that the courts are less likely to be captured than the regulating agencies.

Given these different elements, we can survey some contributions which have compared the two

[4] See Porrini (2001).

different broadly defined instruments. Most of the time, the instruments are studied independently as if the choice was between one or the other. We look at contributions which consider the view that ex ante safety regulation and ex post liability of harms are not simply substitutes but can be used, possibly in a more efficient way, as complementary policies to face the internalization issue.

2 COMPLEMENTARITIES AND SUBSTITUTION BETWEEN LIABILITY AND REGULATION

Shavell (1984a, 1984b) compares the liability and safety regulation in terms of the incentives to reduce the level of risk by exerting the socially desirable level of care. He considers generally that neither regulation nor liability leads the parties to exercise the socially desirable level of care for different reasons: on the one hand, the regulatory authorities suffer from asymmetric information problems about the risk and on the other hand, a liability system presents the possibility that the parties would not pay fully for harm and would not even be sued. He considers the case where either the liability system or the regulation system can be used and also the case where both systems can be used jointly, considering that the parties must satisfy regulatory standards and are also subject to liability. His conclusions are that it is generally socially advantageous to use both liability and regulation because in this case the regulatory standard can be lower than if regulation is used alone: liability is improving, in a sense, the efficiency of the regulatory system.

Kolstad, Ulen and Johnson (1999) stress that the two policies may be complements. A preliminary consideration of the authors is that even if the phenomenon of complementary use of ex ante and ex post regulatory policies is widespread, the economic literature has mainly studied the two separately characterizing each of them by different inefficiencies, in particular coming from the asymmetric distribution of information. For instance, the ex post liability system alone is inefficient insofar as the potential injurer is uncertain about whether the court will hold him liable or not. They consider whether the liability system, applied jointly with ex ante regulation, can correct the above inefficiency, at least in part. In addition to the inefficiencies considered by

Shavell, namely the positive probability that the suit will never be brought against the injurer, the limited resources and liability of the injurer to pay the damages, the imperfect knowledge of the regulatory authorities regarding the magnitude of the damage, and the requirement of one single level of care for all injurers, the authors consider the inefficiency in the definition of legal standards which may lead to a different level of precaution from the social optimal one and from the one chosen by the firms. The main conclusions are that when ex ante and ex post policies are used jointly it is efficient to set the regulatory standards at a level that is socially sub-optimal compared with the one set in the case of the regulation system used alone.

In a recent paper, Schmitz (2000) criticizes the above papers which concluded for the complementary use of both ex ante regulation and ex post liability on the basis that both are imperfect. He claims that although, as argued by Kolstand, Ulen and Johnson (1990), liability is inefficient because of the uncertainty regarding the courts' behavior, it is not clear why liability should be used at all given that regulation by itself can always implement socially optimal behavior. In Shavell (1984a), liability is inefficient due to the injurers' limited wealth and regulation is also inefficient because the same regulatory standard applies to all injurers even if socially optimal behavior varies among injurers: the suggestion of using liability and regulation as complementary instruments comes from the fact that the efficiency of liability is limited due to enforcement errors because injurers can escape suits and the magnitude of liability is determined at a suboptimal level. But it seems unsatisfactory that a theory be based on the assumption that not only the courts make mistakes, but that they make the same kind of errors persistently. Schmitz, using a model closely related to Shavell's, shows first that if injurers cannot escape suit and if the magnitude of liability is calculated at an optimal level, it can never be socially advantageous to employ both liability and regulation as complementary instruments when all the injurers face the same wealth constraints. But the joint use of liability and safety regulation can be optimal under the assumption that wealth varies among injurers and in the latter case, the regulatory standard can be set at a level that is lower than the one corresponding to the social optimum when regulation is used alone.

Boyer, Lewis and Liu (2000) examines the further problem that optimal legal standards must

simultaneously induce parties to invest in care and motivate law enforcers to detect violators of the law because it is the threat of being fined or punished that provides incentives to take care. Recent experience reveals that it is difficult for public officials to control the behavior of enforcement agencies and this suggests that law enforcers need to be motivated to detect violators, perhaps by rewarding them according to their success in discovering violations. In such a setting the equilibrium interaction between potential offenders and law enforcers will determine how regulations are observed and enforced. The amount of effort enforcers exert will depend on the perceived likelihood that parties have violated standards, and the likelihood of violation will depend on how vigorously the law is enforced. In turn the behavior of offenders and enforcers will be shaped by the standards determining if a party has violated the law. The strategic interaction between care providers and law enforcers determines the degree of efficiency achieved by the standards. The main finding of Boyer, Lewis and Liu (2000) is that some divergence between the marginal benefits and marginal costs of providing care to prevent accidents is required to control enforcement costs.[5]

Boyer and Porrini (2001) compare three incomplete information contexts in their analysis of the choice of instruments in implementing an environmental protection policy. In the first context, a benevolent regulator maximizes the proper social welfare function (the reference case). In the second context, a private financier, that is an insurer or a banker, maximizes its own profit but is subject to extended liability if and when a firm she finances goes bankrupt following an environmental accident. In the third context, a captured regulator, who benefits from the firm's informational rent or profit through bribes, perks and/or future employment opportunities, is biased in her maximization of the social welfare function. In all three settings, the regulator or financier can determine both the level of accident preventing care to be implemented by submitting the firm to an incentive contract and whether or not the risky activities themselves should be allowed or not to operate or be financed. Boyer and Porrini show that a relatively large cost differential between high and low levels of care, that is a high cost of accident preventing activities, favors the 'extended lender liability' regime. In this case, the 'regulator subject to capture' regime would end up inducing too much care, or too few environmental accidents, and

[5]See also Tiller and Spiller (1999) who analyze of judges or reviewers and agencies or enforcers in a context of strategic decision making regarding the choice of instruments.

allowing the financing of too many risky activities, that is an overdevelopment of environmentally risky industries: the social value of the informational rents or profits so allowed are not large enough in that case to compensate for the social cost of the extra care activities. They show also that a relatively low cost of public funds, that is an efficient non-distortionary taxation system, favors the captured regulator regime. In that case, the 'extended lender liability' regime would end up inducing too little care, or too many environmental accidents, and allowing the financing of too few risky activities, that is an underdevelopment of environmentally risky industries: the benefit so created in terms of a reduced expected cost of environmental accidents are not large enough in this case to compensate for the loss of profits (informational rents) whose social cost is small when the cost of public funds is low.

In the present paper, we develop further the analysis of Boyer and Porrini (2001) by deriving and discussing additional comparative statics results. We first recall in the next section the main characteristics of our model: it is based on the stylized features of a liability system, extended to lenders or covered by insurance contracts, and of a regulation system, that uses a fund financed by taxation; in both cases, the informational problems between parties and the possibility of capture are explicitly present. We characterize, in an incomplete information political economy framework, the conditions under which the specific incentive regulation approach we consider is superior to the specific extended liability approach in terms of social welfare, in particular in terms of the level of precautionary activities and the level of investment in risky businesses and therefore in terms of the probability of environmental accident.

The following factors in the comparison of the relative social efficiency of the two different regimes are considered:

- the differential cost between low and high levels of environmental protection activities,
- the social cost of public funds due to distortionary taxation,
- the net profitability, always positive, of the risky activities when the level of environmental protection activities is high,

- the net profitability, positive or negative, of the risky activities when the level of environmental protection activities is low,
- the level of damages if an accident occurs,
- and finally the importance of the bias in the social welfare function in the case of regulatory capture.

Using this model, different combinations of those parameters will be analyzed and simulated in order to characterize their multifactorial interactions in determining which regime, the extended liability regime or the regulation subject to capture regime, is likely to be more efficient in implementing the environmental protection policy.

3 THE MODEL

It is useful to recall the main features of the model developed in Boyer and Porrini (2001).[6] A firm needs an amount F to invest in a single project. The project is assumed to generate either a low level of net income π_L or a high one π_H with probability θ and $1-\theta$ respectively, the expected net income (before accounting for the expected cost of an accident and the cost of care) being $\bar{\pi} = \theta\pi_L + (1-\theta)\pi_H$. The project is a risky project which can cause an accident with damage d which if it occurred would make the firm bankrupt, that is $d > \pi_H$. The probability of occurrence of such an accident depends on the firm's accident preventing activities e and is denoted by $p(e)$. For matter of simplicity, the accident preventing activities e can be chosen to be at a high level e_h or at a low level e_ℓ, leading respectively to a probability of accident p_h and p_ℓ. Those activities are costly for the firm; we denote the differential cost between the high and low levels as $\Delta\psi$, while normalizing the cost ψ_ℓ of the low level at 0. We assume that the differential cost $\Delta\psi$ and the benefit of care in terms of a reduced probability of an accident $(p_\ell - p_h)d$ are such that it is socially optimal in a full information first best sense that a high level of accident preventing activities be exerted by the firm. We assume without loss of generality that the firm must borrow the full amount of investment F.

[6] The model builds on the modelization of Boyer and Laffont (1997).

We consider two regimes. In the first regime, the firm interacts with a private financier, insurer or banker, who is the residual liable party for the part of environmental damages above the value of the firm's assets. The financier is assumed to be a deep pocket institution (with a non-binding limited liability) which maximizes its own profit when dealing with the firm.[7] In the second regime, the firm interacts with a regulator who is responsible for implementing environmental protection policies regarding both the accident preventing effort level and whether the firm should be allowed to operate or not, so in a sense to be financed of not.[8] For simplicity, we assume a direct financial link between the regulator and the firm, as a reduced form representation of the structural relationships between the regulator, the firm and the financial markets. The regulator maximizes welfare but may be subject to a form of capture by the regulated firm. Under this regulatory regime, the regulator takes into account in her complex relationships with the firm that the latter must be financially viable and that financial contracts have significant impacts on the firm's incentives to exert a high level of accident preventing activities.

We want to concentrate here on the difficulty for regulators and financiers to directly observe the accident preventing activities of firms. This relative difficulty to observe the way firms choose to prevent the occurrence of catastrophic accidents is a significant and realistic characteristic of the challenging task of designing efficient policies for proper environmental protection. Quite often, the prevention and contingency plans are public and if not they are at least observable by concerned parties but the daily implementation of those plans is not. This unobservability of prevention and contingency plans or of their implementation is a major source of information asymmetries between the external stakeholders and the firm managers or owners and it imposes significant constraints on the design and implementation of environmental policies. If those constraints are not adequately taken into consideration, the policies will turn out to be either socially too costly or inefficient and unable to achieve the objectives pursued.

To take into account this feature of the environmental protection challenge, we consider the following information structure: the realized profit level is assumed to be observable by everyone

[7] Many authors have considered the topic of extended liability for environmental accidents. See among others Pitchford (1995), Heyes (1996), Boyer and Laffont (1996), Boyd and Ingberman (1997).

[8] See among others Hahn (1990), Laffont (1995), Boyer and Laffont (1999).

while the level of self-protection activities is assumed to be a private information of the firm and is therefore observable neither by the regulator, nor by the private financier. The relationships between the regulator and the firm and between the private financier are modeled in a principal-agent framework. The timing of the interplay between the principal (either the public regulator or the private banker or insurer) and the firm is modeled as follows in both regimes considered. The principal offers a financial contract to the firm making explicit the payments to be made if the firm is financed; since the level of profit is observable but the level of accident preventing activities is not, the payments by the firm will optimally depend on the level of profits[9] but not on the level of accident preventing activities. To make clearer the timing of payments and the occurrence of an accident, we consider the model as a two-period model with the accident preventing activities being implemented in period 1 and the accident occurring or not in period 2; the firm project must be financed in each period and the probabilities of high and low profit levels remain the same in both periods. Once the investment is made, the accident preventing activities level e is chosen and the project realized in period 1, then the profit level is observed and a payment is made to the principal according to the terms of the financial contract. Then in period 2 the firm is refinanced and invests F again, the profit level is observed and an accident occurs or not. A payment is made to the principal according to the financial contract and, if an accident occurs, cleanup costs are distributed according to the system in force.

We will characterize and compare three solutions. The benchmark solution will correspond to the case where a benevolent regulator, not subject to capture, decides whether or not the firm should operate, that is to be financed or not, and chooses directly the financial contract offered to the firm in order to maximize a utilitarian social welfare function in which the informational rent of the firm is properly accounted for. As mentioned above, this is meant to be a reduced form representation of the complex relationships between the regulator, the firm and the financial markets. The second solution will be obtained when the decision whether the firm should operate or not is delegated to a private financier, banker or insurer who, under an extended lender liability, decides to finance or not the firm and to offer a financial and/or an insurance contract that maximizes its own expected profit function in which the informational rent of the

[9]Hence the financial contract will not be a standard loan contract.

firm is not present. The third solution will be obtained when the captured regulator decides whether the firm should operate or not and chooses the financial contract offered to the firm: the captured regulator maximizes a distorted social welfare function in which the informational rent of the firm will be overvalued by a factor $K > 1$.

The utilitarian social welfare function we use to compare the extended liability regime and the regulation subject to capture regime contains three terms: a first term corresponds to the expected net observable benefits of the firm's activities or project; a second term corresponds to the expected cost of an accident (probability of accident times the amount of damage); a third element corresponds to the informational rent or supra competitive profit that the firm can capture or hide. The existence of the informational rent or supra competitive profit comes from the assumption that the level of the firm's precautionary activities are not observable (moral hazard) and from the net social value of nevertheless inducing proper care to reduce the probability of an environmental accident. If this net social value is high enough, it will be welfare enhancing to impose on the welfare maximization program an incentive compatibility constraint. However, if this net social value is relatively low, then it may be better from a social point of view not to induce a high level of accident preventing activities and to tolerate a higher probability of accident when the firm is nevertheless allowed to operate.

We assume the existence of a social cost of public funds λ due to distortionary taxation in the economy.[10] The observable profit of the firm could be used to reduce the general distortionary taxes and will thus enter the social welfare function with a weight of $(1+\lambda)$ to explicitly represent its social value, that is its potential social value. Similarly, the expected cost of an accident enters the social welfare function with a weight of $(1+\lambda)$ because the government will have to cover that cost one way or another, either directly or through the taxation rules (tax deductible expenses for cleaning up the polluted areas and/or for compensating the victims, for instance). Finally, the informational rent that the firm can capture or hide cannot be used, even potentially, to reduce distortionary taxation because it is not observed and will thus enter the social welfare

[10] There is a large literature on this complex problem. For a balanced view, the reader is referred to the following sources: Pigou (1947), Stiglitz and Dasgupta (1971), Ballard and Fullerton (1992) and Kaplow (1996). Jones, Tandon and Vogelsang (1990) derive estimates indicating that λ is of the order of 0.3 in developed countries and higher in developing ones.

function with a weight of 1 to properly represent its utilitarian (private) value. The existence of a social cost of public funds is an important and realistic feature of regulatory framework and social welfare accounting: as we will see, it will lead under some conditions to distortions in the accident preventing effort levels and to distortions also in the decision to finance or not the firm's risky activities, so to allow those activities.

4 AN INTUITIVE DISCUSSION OF THE RESULTS

In a complete information context, the first best solution is feasible and entails a high level of precautionary activities and the financing of the firm's risky activities under the condition that, given the high level of effort, the expected net income minus the fixed investment cost, the expected cost of the accident and the cost of accident preventing activities, is positive or at least non-negative, a condition that is met by assumption. This full information first best solution is achieved if we have a benevolent regulator or a captured regulator because even if the two regulators differ by their treatment of the firm's informational rent, the rent is zero under full information. With extended liability of a deep pocket private bank or an insurer as financier, the full information first best allocation is also achieved at the Nash equilibrium of the game played by the firm and the financier since the extended lender liability or the full insurance contract make both the banker and the insurer internalize the full expected cost of an accident and therefore implement the social welfare maximizing solution.

Under an asymmetric information structure and with limited liability of the firm, the internalization of externalities becomes a more difficult problem. The social optimum corresponds to the maximization of the social welfare function under the following conditions or constraints: the incentive compatibility constraint requiring that the firm be induced to choose an high level of precautions which in general implies that a costly rent be left to the firm; the limited liability of the firm requiring that the repayment levels not exceed the corresponding profit levels; the individual rationality constraint of the privately informed firm stating that the firm's expected profit cannot be negative. Under limited liability, if the accident occurs, the firm will

be judgment-proof[11] for damages above its profit level, so moral hazard variables cannot be simply and costlessly controlled by imposing appropriate penalties on the risk neutral firm and the latter will in general be able to capture an informational rent.

The rent the firm can obtain because of its superior information on its own accident preventing activities is given by the difference between its expected profit when it is not induced to exert a high level of care and its expected profit when it is so induced. Because of the social cost of public funds, it will be welfare enhancing to make this rent as small as possible by adjusting the payments stipulated in the financial contract such that the rent is minimized under that condition that the contract be incentive compatible. Boyer and Porrini (2001) show that this rent $\mathcal{R}$ (net of the cost $\Delta\psi$ of exerting a high level of care) is given by[12]

$$\mathcal{R} \equiv (1 - p_h)\frac{\Delta\psi}{p_\ell - p_h} - \Delta\psi.$$

Under moral hazard (non-observability of precautionary activities), the social optimum, corresponding to the benevolent regulator solution, is characterized by a high level of accident preventing activities if and only if the net social cost of the firm's informational rent plus the differential cost of precautionary activities is less than or equal to the difference in the expected cost of an accident under the high and the low levels of precautionary activities. Financing occurs then if the net social value of the firm's activities under full information is larger than the net social cost of the firm's informational rent (rather than simply larger than 0, as in the first best full information context). This social optimum under moral hazard rule differs from the first best full information rule because of the presence of the informational rent to be given up to the firm when the benevolent regulator wants to induce a high level of care. The benevolent regulator cannot avoid giving up that rent to induce a high level of care and will therefore take into account the net social cost of that rent in deciding if the firm should be allowed to operate or not and in deciding what level of accident preventing activities should be implemented. If that net social cost of the rent is large, the benevolent regulator may prefer, in maximizing

[11] See Summers (1983) and Shavell (1986).

[12] Incentive compatibility requires that the firm gains in exerting a high level of care, that is, letting EP be the expected payments made by the firm under the financial contract, $(1 - p_h)(\bar{\pi} - EP) - \Delta\psi \geq (1 - p_\ell)(\bar{\pi} - EP)$ implying that $EP \leq \bar{\pi} - \Delta\psi/(p_\ell - p_h)$. Substituting the latter into the former we obtain that the rent the firm can get when induced to exert the high level of care is $(1 - p_h)(\Delta\psi/(p_\ell - p_h)) - \Delta\psi$.

social welfare, to induce a low level of accident preventing activities, generating thereby a high probability of environmental accidents. It may even turn out that the benevolent regulator will prevent the firm from operating or being financed even if the firm's activities or project is socially valuable under full information.

Under an extended lender liability framework or under a compulsory full insurance contract, the principal is either a private banker or a private insurer. As in the benevolent regulator case, the full expected cost of an accident is properly internalized given that the banker or the insurer is the residual claimant of that cost. The difference is in the treatment of the firm's informational rent, which appears only when the high level of effort is induced. Hence, the comparison between the two solutions rests on their different evaluation of the firm's rent when a high level of care is induced. For the private financier, banker or insurer, the cost of the rent is equal to the amount of the rent itself while for the benevolent regulator the net cost is smaller because she considers the social value of that rent in the social welfare function. This makes the private financier less willing than the benevolent regulator to lend and less willing also to induce a high level of accident preventing activities. Hence this undervaluation of the social value (overvaluation of its cost) of the firm's unavoidable informational rent leads to insufficient financing and too little care activities induced by the bank or the insurer as compared with the solution a benevolent regulator would choose to implement. If the banker or the insurer chooses to let the firm exert a low level of care in preventing accidents, there will be no rent and therefore the bank lends as often as the benevolent regulator would in that case. Hence, an extended lender liability or full (strict) insurance regime will generate a welfare cost because of insufficient financing of risky activities and of inducing high care levels not often enough.

Because the captured regulator overvalues the firm's informational rent in her version of the social welfare function, due to her indirect interests in the firm's informational rent or profit, and because this informational rent is obtained by the firm only when it is induced to choose the high level of accident preventing activities, the captured regulator induces a high level of accident preventing activities more often than the benevolent regulator does. When she induces a high level of care conceding a rent to the firm, she also lends more often than called for by

the second best optimal investment rule again because she overvalues the firm's rent or profit in its objective function. The net social cost of the firm's informational rent or supra competitive profit is undervalued by the captured regulator and therefore, the capture of the regulator leads to overcare and to overinvestment in the case of high level of care as compared with the solution a benevolent regulator would choose to implement. When a low level of care is induced, then no rent is left to the firm and the investment rules of the captured regulator and the benevolent regulator are the same. Hence, a regulation subject to capture regime will generate a welfare cost because it leads to financing of risky activities too much and to inducing high levels of accident preventing activities too often. A formal presentation of the results is given in the Appendix.

5 A GRAPHICAL REPRESENTATION OF THE CHOICE OF INSTRUMENTS

We can compare the two regimes considered, the extended liability regime and the regulation subject to capture regime, by referring to the following illustrative figures. In those figures, BR stands for the solution (the investment rule, that is allowing the firm to operate or not, and the level of accident preventing activities) implemented by the "benevolent regulator", CR stands for the solution implemented by the "captured regulator" and "PF" stands for the solution implemented by the "private financier, banker or insurer". The five graphs presented here are only some of the graphs one could look at but they are illustrative of what results can be derived under a formal analysis of the choice of instruments in implementing a set of environmental policy objectives.

In each figure, the numbers associated with the different curves or lines correspond to the equation numbers in the Appendix. We indicate by Φ_1 the region, in the particular parameter space represented by the coordinates, where both the extended liability or full insurance regime and the regulation subject to capture regime are equivalent to the benevolent regulator in the sense that they induce a high level of accident preventing activities and implement the same investment or financing rule. Hence, in that region, both regimes are equivalent and generate no

welfare loss. We indicate by Φ_2 the region where again both the extended liability regime and the regulation subject to capture regime are equivalent to the benevolent regulator in the sense that they induce a low level of accident preventing activities and implement the same investment or financing rule. Hence, in that region, both regimes are again equivalent and generate no welfare loss. In regions Ω and Γ, the two regimes differs, the regulation subject to capture regime being welfare superior to the extended liability or full insurance regime in region Ω and welfare inferior in region Γ.

Let us consider Figure 1. The case depicted in this figure is such that the project is valuable even if the low level of accident preventing activities is exerted, that is (3) is satisfied. Hence the firm will always be allowed to operate or be financed. In region Ω, the regulation subject to capture regime is equivalent to the benevolent regulator in the sense that both induce a high level of accident preventing activities and both let the firm operate. Hence, in that region, the regulation subject to capture regime implements the social welfare maximizing solution and therefore generate no welfare loss. However, in that region, the firm is always financed under the extended liability or full insurance regime but with a low level of accident preventing activities and therefore generate a welfare loss: there would be too many environment damaging accidents. In region Γ, the extended liability or full insurance regime is equivalent to the benevolent regulator in the sense that both induce a low level of accident preventing activities and both let the firm operate or be financed. Hence, in that region, the extended liability or full insurance regime implements the social welfare maximizing solution and therefore generate no welfare loss. However, in that region, the regulation subject to capture regime always finances the firm but it induces a high level of accident preventing activities and therefore generate a welfare loss: it would imply too few environment damaging accidents. In this region, the welfare maximizing solution calls for a low level of accident preventing care because the social cost of the informational rent that the firm can obtain if asked to exert a high level of care is too high. It is better, from a social welfare point of view, to tolerate a higher probability of accident with no informational rent for the firm than to reduce the probability of accident together with abandoning a costly rent to the firm.

Insert Figure 1 here

Suppose that in Figure 1 the net social opportunity cost of public funds is $\lambda = 0.6$. Then, as the differential cost between the high and low levels of accident preventing activities $\Delta\psi$ increases, we go from region Φ_1 where both regimes are equivalent and generate no welfare loss to region Ω where, once (4) is crossed, the private financier would find unprofitable to induce the firm to exert a high level because with a higher $\Delta\psi$ the rent to be abandon to the firm becomes too large. In spite of extended liability and therefore of the full internalization of the expected cost of an accident, the private financier finds more profitable to let the probability of accident be relatively large. In that region the regulation subject to capture is preferred. But for a larger value of $\Delta\psi$, we move into region Γ where the social optimum under moral hazard calls for a low level of accident preventing effort and no rent because the otherwise unavoidable rent increases with the differential cost of care. However, because the captured regulator has a vested interest in keeping the firm's rent or profit high, and since this rent is obtained only if a high level of effort is induced, she keeps inducing the firm to exert a high level of effort to reduce the probability of environmental accidents. But in so doing, she moves away from the social optimum which calls in this region Γ for the elimination of the rent at the expense of a higher probability of accident. In that region, the investment and effort policies of the private financier and the benevolent regulator coincide and therefore the extended liability or full insurance regime is preferred. As the differential cost $\Delta\psi$ increases even more, we move into region Φ_2 where the rent level becomes so high that even the captured regulator opt, as well as the private financier regime, for letting the firm operate at a low level of effort but with no rent.

Let us now suppose that the differential cost between the high and low levels of accident preventing activities $\Delta\psi$ is fixed at the 0.5 level. As the social cost of public funds λ increases from 0 to 1, we move successively into regions Ω, Γ and Φ_2. When the value of λ becomes large enough to cross the boundary (1) – note that this occurs earlier for larger values of $\Delta\psi$ – the cost of the rent that the captured regulator would leave to the firm becomes too high and it is better to opt for the private financier extended liability or full insurance regime which leaves no rent to the firm: the higher probability of accident with the private financier regime is better,

from a social welfare point of view, than the larger rent with the captured regulator regime.

Hence, Figure 1 shows that "larger" values of the social opportunity cost of public funds – above (1) – favors the private financier extended liability or full insurance regime as the preferred instrument, while "lower" values of the differential cost between the high and low levels of accident preventing activities – to the left of (1) – favors the regulation subject to capture regime as the preferred instrument to implement the socially optimal environmental policy both in terms of allowing (and financing) or not the firm to operate and in terms of the level of accident preventing activities.

Let us consider Figure 2. In the case depicted in this figure we consider the same variable parameters (coordinates) as in Figure 1 and the same fixed values for the other parameters except for the probability of accident under a low level of care p_ℓ which is now set at 0.3 rather than 0.1; this higher probability of accident when the firm exerts a low level of care implies that the firm project is not socially valuable under full information when the low level of accident preventing activities is exerted. We now find that in region $\hat{\Omega}$, the private financier solution calls for not financing the firm: under extended liability or full insurance, the no rent solution with a low level of accident preventing activities is not profitable for the private financier. But the social optimum under moral hazard calls for letting the firm operate and be induced to exert a high level of care. The captured regulator will implement such a solution and is therefore the preferred instrument in this region. In spite of the fact that there will be more environment damaging accident with the captured regulator regime than with the private financier regime, it is socially optimal to face the risk of such accidents. However, as we move into region $\hat{\Gamma}$, either because of a higher level of the social cost of public funds λ or a higher differential cost between the high and low level of accident preventing activities, the social optimum is to prevent the firm from operating while the captured regulator would rather let it operate with a high level of effort to generate an informational rent in which she has some interest. In this region, the private financier is the preferred instrument: the rent captured by the firm under a high level of effort is too large (higher $\Delta\psi$) or too costly (higher λ) compared to the social value of the firm or project to justify its operation. As in region $\hat{\Omega}$, there will be more environment damaging

accident with the captured regulator regime than with the private financier regime, but now the social cost of the unavoidable rent has become too large to make it socially profitable to face the risk of such accidents.

Insert Figure 2 here

Let us suppose as before that the net social opportunity cost of public funds is $\lambda = 0.6$. Then, as the differential cost between e_h and e_ℓ goes up, we move from the region where neither the private financier regime nor the captured regulator regime generate any welfare loss to region $\hat{\Omega}$ where, once (5) is crossed, the private financier would find unprofitable to finance the firm.[13] In that region the regulation subject to capture is preferred. But for a larger discrepancy cost, we move into region $\hat{\Gamma}$ where the social optimum under moral hazard calls for not financing the firm. However, because the captured regulator has a vested interest in keeping the firm's rent or profit high, and since this rent is obtained only if a high level of effort is induced and the firm is in operation, she keeps letting the firm operate and inducing it to exert a high level of effort to reduce the probability of environmental accidents. But in so doing, she moves away from the social optimum which calls in this region $\hat{\Gamma}$ for preventing the firm from operating. In that region, the investment policies of the private financier and the benevolent regulator coincide and therefore the extended liability or full insurance regime is preferred. As the differential cost increases even more, we move into region $\hat{\Phi}_2$ where the rent level becomes so high that even the captured regulator opt, as well as the private financier, for not financing the firm and therefore neither generate a welfare loss.

Let us now suppose that the differential cost $\Delta\psi$ is fixed at the 2.5 level. As the social cost of public funds increases from 0 to 1, we move successively into regions $\hat{\Omega}$, $\hat{\Gamma}$ and $\hat{\Phi}_2$. When the

[13] We consider a strict liability regime with the banker or insurer fully liable for damages above the firm's assets. In some cases, a partial liability system, as discussed by Boyer and Laffont (1997), may be better if there is some room to maneuver between the need to induce the private financier to monitor the firm and provide it with the incentives to exert a high level of effort and the need to finance the firm whenever it is socially valuable to do so. In Figure 2, making the private financier partially liable would move (4) to the left and (5) to the right and lead to a welfare improvement. Similarly, under a negligence rule, as discussed by Pfaff and Sanchirico (2000), the 'integrated organization', that is the private financier together with the firm, may fined too heavily for violations of the regulations as compared to an optimal fine level which could be a decreasing function of the organization's monitoring and disclosure rules and efforts.

value of λ becomes large enough to cross the boundary (2) – note that again this occurs earlier for larger values of $\Delta\psi$ – the cost of the rent that the captured regulator would leave to the firm by letting it operate and inducing a high level of accident preventing activities becomes too high and it is better to opt for the private financier regime which will not finance the firm at all: the no financing solution of the private financier regime is now better, from a social welfare point of view, than letting the firm operate even with a high level of accident preventing activities which the captured regulator regime would imply.

Hence, when the firm project is socially valuable only if a high level of care is exerted, Figure 2 shows that "larger" values of the social opportunity cost of public funds – above (2) – favors the private financier regime as the preferred instrument, while "lower" values of the differential cost between the high and low levels of accident preventing activities – to the left of (2) – favors the regulation subject to capture regime as the preferred instrument to implement the socially optimal environmental policy both because it would allow the firm to operate, contrary to the private financier regime, and because it would induce the firm to choose a high level of accident preventing activities.

Let us now consider Figure 3 where the social cost of public funds is fixed at 0.3 and the variable parameters are now the differential cost between high and low levels of accident preventing activities as before and the cost of an accident d. It should be stressed that we do not assume a distribution function for d. The level of damages if an accident occurs remains fixed but we consider different levels of this fixed value between π_H and 50. The parameter values of this case are otherwise the same as in Figure 1 and therefore the firm project is valuable under a low level of care. The regions Φ_1, Ω, Γ and Φ_2 have the same interpretation as before: the two regimes are equivalent instruments in Φ_1 and Φ_2, the regulation subject to capture is preferred in region Ω and the private financier extended liability or full insurance regime is preferred in region Γ. The firm is financed in all regions but the level of accident preventing activities differ between regions and regimes.

Insert Figure 3 here

Let us now suppose that the differential cost between the high and low levels of care $\Delta\psi$ is fixed at the 0.1 level. As the cost of an accident d increases from $\pi_H = 10$ to 50, we move successively into regions Φ_2, Γ, Ω and finally Φ_1. For relatively low values of d, it is socially preferable to let the firm operate with a low level of accident preventing activities, the reason being that the expected cost of an accident is not high enough to justify the social cost of the informational rent or supra competitive profit the firm would enjoy if the principal wants to induce it to exert a high level of care. Both regimes considered implement the social optimum under moral hazard and therefore neither generate a welfare cost. When the value of d becomes large enough to cross the boundary (6) – note that this occurs later for larger values of $\Delta\psi$ since a larger $\Delta\psi$ means a larger informational rent – the expected cost of an accident becomes large enough for the captured regulator to prefer inducing the firm to choose a high level of care, allowing it to get an informational rent, even if the social optimum still calls for not doing so. In region Γ, the private financier remains unwilling to abandon a rent to the firm and prefers, as the benevolent regulator does, to finance the firm and face the higher probability of an accident. Hence the private financier implements the social optimum under moral hazard solution and is therefore the preferred instrument: the higher probability of accident with no informational rent is better, from a social welfare point of view, than the lower probability of accident with a positive informational rent under the captured regulator regime. As d increases more and crosses the boundary (1), the larger cost of an accident now justifies that the firm be induced to exert a high level of care even if that implies a positive rent or higher profit for the firm – note that this occurs later for larger values of the differential cost between the high and low level of care. However, the private financier still prefers not to induce the firm to choose a high level of accident preventing activities and face the higher risk of an accident for which she is the residual liable party. In region Ω, the captured regulator implements the social optimum under moral hazard and is therefore the preferred instrument: the lower probability of an accident obtained in the captured regulator regime at the cost of an informational rent or a supra competitive profit for the firm is better than the higher probability of accident with no rent which the private financier regime would implement. Finally, when the value of d goes over boundary (4) which is also increasing with $\Delta\psi$, the cost of an accident is now high enough that both regimes prefer to induce the firm to choose a high level of care as the benevolent regulator does and therefore

neither generate a welfare loss.

Let us suppose now that the cost of an accident is fixed at 30. Then, as the differential cost between e_h and e_ℓ goes up, we move from the region Φ_1 where both the private financier regime and the captured regulator regime induce the firm to choose a high level of care and therefore neither generate any welfare loss to region Ω where, once (4) is crossed, the private financier would find unprofitable to induce a high level of care anymore because the level of the rent necessary to achieve this is now too high. In that region the regulation subject to capture is preferred. But for a larger discrepancy cost, we move into region Γ where the social optimum under moral hazard calls for a low level of accident preventing activities. However, because the captured regulator has a vested interest in keeping the firm's rent or profit high, and since this rent is obtained only if a high level of effort is induced, she keeps inducing the firm to exert a high level of effort to reduce the probability of environmental accidents. But the investment policies and prevention policies of the private financier and the benevolent regulator coincide and therefore the extended liability or full insurance regime becomes the preferred instrument. As the differential cost increases even more, we move into region Φ_2 where the rent level becomes so high that even the captured regulator opt, as well as the private financier, for a low level of care and therefore neither generate a welfare loss.

Figure 3 shows that more costly accidents favors the captured regulator regime over the private financier extended liability or full insurance regime and that the level of d at which the switch occurs depends on the differential cost $\Delta\psi$: the higher this differential cost, the higher the critical value of d.

Let us now consider Figure 4 where the variable parameters or the coordinates are now the social opportunity cost of public funds and the capture factor K. The cost of an accident is fixed at 20 and the differential cost between the high and low levels of accident preventing activities is fixed at 0.6 and the other parameters are fixed at their levels in Figure 3 and therefore the firm project is valuable under a low level of care. The regions Φ_1, Ω, Γ and Φ_2 have the same interpretation as before. Hence, the firm is always financed the level of accident preventing activities differ between regions and regimes. Note however that the region Φ_1 where the firm would be induced

to exert a high level of care in all regimes is empty in Figure 4.

Insert Figure 4 here

Let us suppose that the capture factor K is fixed at the 1.2 level. As the social opportunity cost of public funds λ increases from 0 to 1, we move successively into regions Ω, Γ and finally Φ_2. For relatively low values of λ, it is socially preferable to induce the firm to choose a high level of accident preventing activities, the reason being that the social cost of the informational rent is rather small. But only the captured regulator is willing to induce the firm to behave that way. The private financier prefers the firm to operate under a low level of care because the level of the rent to be abandoned to the firm is otherwise too large. Hence, the regulation subject to capture regime is preferred. As the value of λ increases and crosses boundary (1), the social cost of the informational rent increases and the social optimum under moral hazard now calls for a low level of care with no supra competitive profit for the firm. However, the level of λ is still not too high, between boundaries (1) and (6), so that the captured regulator prefers to induce the firm to choose a high level of care, the reason being that the captured regulator has a vested interest in the supra competitive profit of the firm and that the rent is considered by the captured regulator as not too costly as long as λ is below boundary (6). Hence in this region, the private financier under extended liability or compulsory full insurance is preferred: the higher probability of accident is better from a social welfare point of view to the supra competitive profit the firm would be able to obtain with a high level of accident preventing activities. Finally, as λ becomes relatively large, the social cost of the informational rent becomes too high and even the captured regulator prefers to let the firm operate with a low level of care. In region Φ_2, both regimes considered are equivalent and there are no welfare loss with either of them. It is interesting to note that boundary (1), at which the preferred instrument or regime switches from the regulation subject to capture to the private financier one, is independent of the capture factor K whereas boundary (6), at which the captured regulator ceases to induce the firm to choose a high level of accident preventing activities and thus implements again the social optimum under moral hazard, is increasing with K.

Let us now suppose that the social opportunity cost of public funds λ is fixed at the 0.3 level. Then, as the capture factor K increases from 1 to 2, we move successively into regions Φ_2 and Γ, the other regions of interest Φ_1 and Ω being empty in Figure 4. For low values of K, it is socially preferable to let the firm operate with a low level of accident preventing activities, the reason being that the social cost of the informational rent, which is independent of K, is relatively large given that λ is at 0.3 and $\Delta\psi$ is at the 0.6 level. Both the captured regulator and the private financier are unwilling to induce the firm to choose a high level of care and therefore neither generate a welfare loss. As the capture of the regulator becomes more important, that is as K increases above the boundary (6) – this happens later for larger values of λ – we move into region Γ where the captured regulator is now willing to induce the firm to choose a high level of effort, reducing the probability of an accident but letting the firm obtain a costly informational rent. In so doing, the captured regulator moves away from the social optimum under moral hazard while the private financier remains unwilling to induce a high level of care. The private financier under extended liability or compulsory full insurance becomes the preferred instrument.

Let us now consider Figure 5 where the two variable parameters or coordinates are the social opportunity cost of public funds λ and the probability of the low level of profit θ. The cost of an accident is fixed at 20, the differential cost between the high and low levels of accident preventing activities is fixed at 0.6 and the capture factor is fixed at 1.2 as before. The firm project is valuable under a low level of care if and only if the probability of the low level of profit θ is below 0.8; for $\theta > 0.8$, condition (3) is not satisfied. The regions Φ_1 and $\hat{\Phi}_1$ are empty in Figure 5 and the regions Ω, Γ and Φ_2 together with $\hat{\Omega}$, $\hat{\Gamma}$ and $\hat{\Phi}_2$ have the same interpretation as before. In Ω and $\hat{\Omega}$, the regulation subject to capture regime is the preferred instrument because in this region of the parameter space the private financier prefers, if $\theta \leq 0.8$, to finance the firm with a low level of accident preventing activities because otherwise the level of the informational rent is too high or, if $\theta > 0,8$, to not finance the firm at all, while the captured regulator implements the social optimum under moral hazard by allowing the firm to operate while inducing it to exert a high level of care. In region Γ and $\hat{\Gamma}$, the private financier with extended liability or full compulsory insurance regime is the preferred regime because in these regions, the private financier implements the social optimum under moral hazard: either,

if $(\lambda, \theta) \in \Gamma$, by financing the firm but with a low level of care or, if $(\lambda, \theta) \in \hat{\Gamma}$, by not financing the firm. In Γ and $\hat{\Gamma}$, the captured regulator allows the firm to operate and induces it to exert a high level of effort and in so doing moves away from the social optimum under moral hazard. In region Φ_2 and $\hat{\Phi}_2$, both regimes, the captured regulator regime and the private financier regime, implement the social optimum under moral hazard which calls in Φ_2 for financing the firm or allowing it to operate with a low level of accident preventing activities and in $\hat{\Phi}_2$ for not allowing the firm to operate.

Insert Figure 5 here

Let us suppose that the probability of the low level of profit is fixed at the 0.6 level. As the social opportunity cost of public funds λ increases from 0 to 1, we move successively into regions Ω, Γ and finally Φ_2, a case similar to the one discussed in Figure 4 except that in the present case, boundary (6) is the same for all values of $\theta \in (0, 0.8]$. Let us suppose now that the probability of the low level of profit is fixed at the 0.82 level. As the social opportunity cost of public funds λ increases from 0 to 1, we move successively into regions $\hat{\Omega}$, $\hat{\Gamma}$ and finally $\hat{\Phi}_2$. When the value of λ crosses boundary (2), the firm project ceases to be socially valuable. Under full information, the firm project would be socially valuable only if the firm exerts a high level of accident preventing activities but under incomplete information (moral hazard) it ceases to be socially valuable even with a high level of care because of the social cost of the unavoidable informational rent: it is then better to prevent the firm from operating which is what the private financier would end up doing by refusing to finance the firm in that region of parameter space. However, because of her indirect interest in the firm's supra competitive profit, the captured regulator would still, in region $\hat{\Gamma}$, finance the firm and induce it to exert a high level of care, thereby implementing the full information first best optimum but not the social optimum under moral hazard which calls for shutting down the firm: because of the social opportunity cost of public funds, income distribution matters and it is no more sufficient that the first best be attained. As the social opportunity cost of public funds increases above boundary (7), the captured regulator then finds the social cost of the informational rent too high and ceases to allow the firm to operate, thereby implementing, as well as the private financier regime, the social optimum under moral hazard.

Let us now suppose that the social opportunity cost of public funds λ is fixed at the 0.03 level. Then, as the probability of the low level of profit θ increases toward 1, we are successively in regions Ω, $\hat{\Omega}$ $\hat{\Phi}_2$. For low values of θ, that is for a firm project with a large expected profit level, it is socially preferable to let the firm operate and to induce it to choose a high level of accident preventing activities, the reason being that the social cost of the informational rent, which is independent of θ, is relatively low given that λ is at 0.03 and $\Delta\psi$ is at the 0.6 level. That is the policy the captured regulator would then implement contrary to the private financier who would prefer to finance the firm with a low level of care in order to avoid paying the unavoidable rent if a high level of care is induced. Hence the captured regulator is the preferred regime. As θ increases, the financial profitability $\bar{\pi}$ of the project decreases, and we eventually move into region $\hat{\Omega}$ where the firm/project is socially valuable only if a high level of care is induced. Since the private financier would not finance the firm in $\hat{\Omega}$, the captured regulator which implements the social optimum under moral hazard is the preferred regime. When the value of θ crosses boundary (2), the firm ceases to be socially profitable whatever the level of care – this occurs later for smaller values of the social opportunity cost of public funds – and the social optimum calls for preventing the firm from operating. However, because of her interest in the firm's supra competitive profit, the captured regulator keeps allowing the firm to operate and inducing a high level of effort, making the private financier under extended liability or compulsory full insurance the preferred instrument. Eventually, as θ increases even more, we move into region $\hat{\Phi}_2$ and both regimes implement the social optimum under moral hazard and the firm is not financed.

6 CONCLUSION

We compared in this paper two major instruments to achieve environmental policy objectives. We followed a formal and structured analytical approach to consider the interactions between different decision makers such as governments, firms, regulators and financiers, and we took account of the recent debate on the lenders' liability solution (*American Economic Review*, June 2001). We considered a stylized but explicit extended liability system and modeled the relationship between the financier as a residual liable party and the firms. Moreover, the model we

developed includes political economy considerations, namely through the presence of asymmetric information and capture features, and the instruments compared are in that sense imperfect but realistic instruments. We represented our analysis through different graphs allowing a more intuitive discussion of the implications of using different instruments. We showed how the cost of the accident preventing activities, the social opportunity cost of public fund, the size of the environmental damage, the bias factor in case of regulatory capture and the accident probability can influence the choice between *ex ante* policy instruments such as a regulatory agency and *ex post* policy instruments such as a liability system.

The instruments we characterized are sophisticated version of the statute-based regulatory schemes and tort law systems. We considered incentive regulation rather than command and control regulation to avoid giving at the outset an advantage to liability systems in terms of more adequate exploitation of the decentralized and asymmetric distribution of informations. Similarly, we considered an extended strict liability system to avoid giving at the outset an advantage to the regulatory system which would otherwise be better able to internalize the judgment-proof or limited liability constraints all policy implementation instruments must be facing. In practice, these sophisticated versions of the two broad types of instruments we considered may not in general be the ones used at this time in any given jurisdictions. But we nevertheless consider the exercise fruitful and useful given that more and more sophisticated instruments are likely to gain in popularity to implement given policy objective, whether they are related to environmental protection or not.[14]

We were also careful not to tilt the balance one way or another. For example, the regulatory capture process is not modeled simply as a bribe system where the regulated firms would "buy" the decisions of the regulators but rather as a tendency for regulators to be over sensitive to or to put too much emphasis on the interests of regulated firms. Our captured regulator uses the proper social welfare function except for a larger weight given to the firms' rents or supra competitive profits. This overweighing of the firms' rents implies that the captured regulator will *overprotect* the environment in order to allow firms to capture larger informational rents.

[14]See Boyer and Laffont (1999) for a theoretical model of the pros and cons of the emergence of incentive regulation in environmental policy.

So rather than letting the environment unprotected in order to allow firms to increase their profits, a popular version of the capture argument, our captured regulator tend to make the protection of the environment stricter because higher protection standard are conducive to higher informational rents.

Without recalling all the results of thepaper, it is useful to mention some of the most important. First, larger values of the social opportunity cost of public funds favors an extended liability or full insurance regime as the preferred instrument. Lower values of the cost of reducing the probability of accident favors the regulation subject to capture regime. More costly environmental accidents favors the captured regulator regime and the critical level of that cost at which the switch occurs depends on the differential cost between high and low prevention: the higher this differential cost, the higher that critical level. As the regulatory capture bias factor increases above a critical value which increases with the social cost of public funds, the captured regulator begins inducing the firm to choose a high level of prevention and reduce the probability of an accident but in so doing lets the firm obtain a costly informational rent. In such a context, the captured regulator moves away from the social optimum under moral hazard while the private financier remains unwilling to induce a high level of care. The private financier under extended liability or compulsory full insurance becomes therefore the preferred instrument.

APPENDIX

From Boyer and Porrini (2001), we have the following. The benevolent regulator will induce the firm to exert a high level of accident preventing activities if and only if

$$\frac{\lambda}{1+\lambda}\mathcal{R} + \Delta\psi \leq (p_\ell - p_h)d, \tag{1}$$

and will then let the firm operate if and only if

$$2\bar{\pi} - 2F - p_h d - \Delta\psi - \frac{\lambda}{1+\lambda}\mathcal{R} \geq 0. \tag{2}$$

Otherwise, she prefers that the firm exert a low care level and will then let the firm operate if and only if

$$2\bar{\pi} - 2F - p_\ell d \geq 0. \tag{3}$$

The private financier, banker or insurer, under the extended liability and full insurance regime, will induce the firm to exert a high level of accident preventing activities if and only if

$$\mathcal{R} + \Delta\psi \leq (p_\ell - p_h)d, \tag{4}$$

and will then finance the firm if and only if

$$2\bar{\pi} - 2F - p_h d - \Delta\psi - \mathcal{R} \geq 0. \tag{5}$$

Otherwise, she prefers that the firm exert a low care level and will then finance if and only if (3) is satisfied. The captured regulator will induce the firm to exert a high level of accident preventing activities if and only if

$$\frac{1+\lambda-K}{1+\lambda}\mathcal{R} + \Delta\psi \leq (p_\ell - p_h)d, \tag{6}$$

and will then let the firm operate if and only if

$$2\bar{\pi} - 2F - p_h d - \Delta\psi - \frac{1+\lambda-K}{1+\lambda}\mathcal{R} \geq 0. \tag{7}$$

Otherwise, she prefers that the firm exert a low care level and will then let the firm operate if and only if (3) is satisfied.

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FIGURE 1

$[\pi_L = 5,\ \pi_H = 10,\ \theta = 0.5,\ F = 5,\ p_h = 0.05,\ p_\ell = 0.1,\ d = 20,\ K = 1.2]$

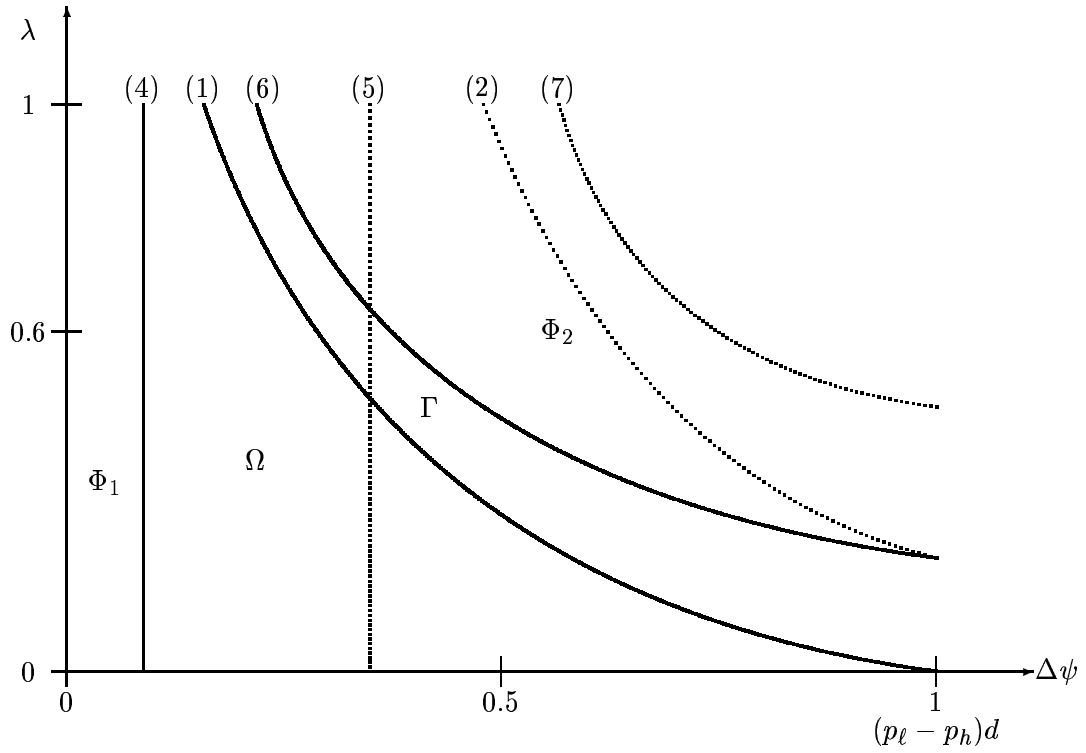

FIGURE 2

$[\pi_L = 5,\ \pi_H = 10,\ \theta = 0.5,\ F = 5,\ p_h = 0.05,\ p_\ell = 0.3,\ d = 20,\ K = 1.2]$

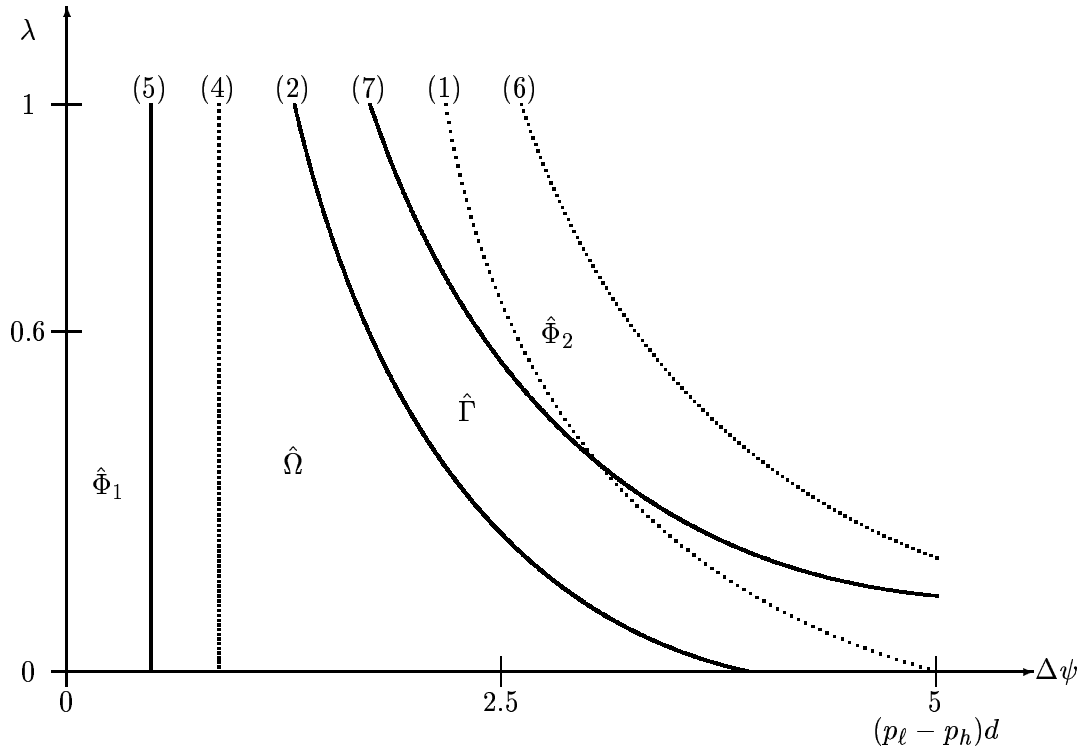

FIGURE 3

$[\pi_L = 5,\ \pi_H = 10,\ \theta = 0.5,\ F = 5,\ p_h = 0.05,\ p_\ell = 0.1,\ K = 1.2,\ \lambda = 0.3]$

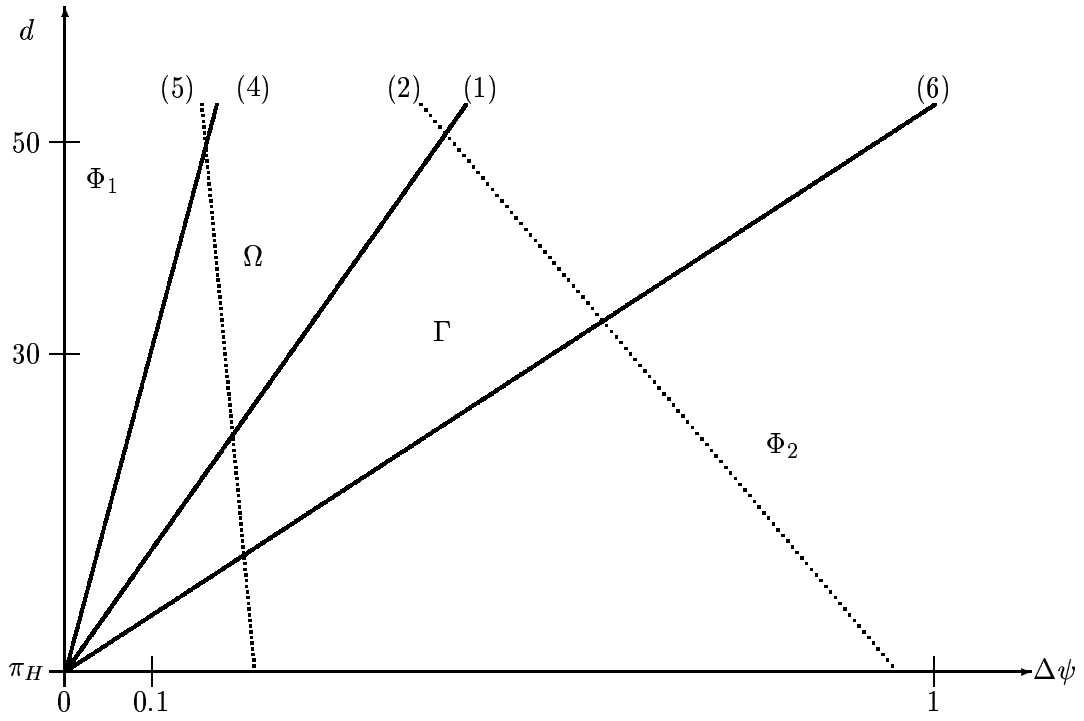

FIGURE 4

$[\pi_L = 5,\ \pi_H = 10,\ \theta = 0.5,\ F = 5,\ p_h = 0.05,\ p_\ell = 0.1,\ d = 20,\ \Delta\psi = 0.6]$

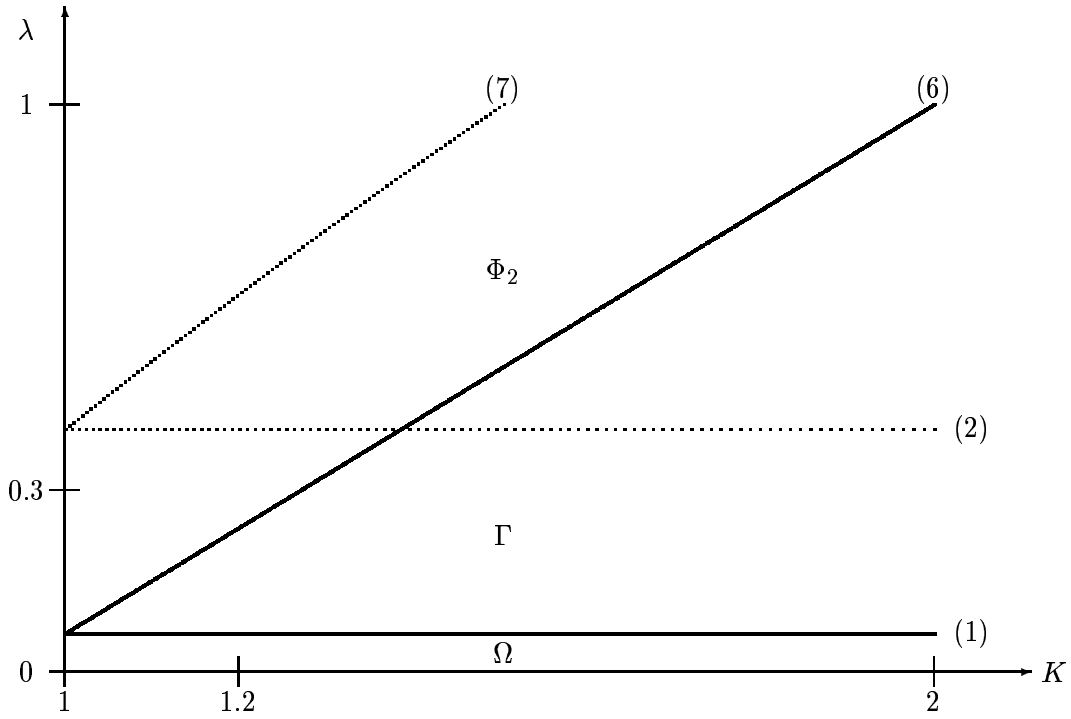

FIGURE 5

$[\pi_L = 5,\ \pi_H = 10,\ F = 5,\ p_h = 0.05,\ p_\ell = 0.1,\ d = 20,\ K = 1.2,\ \Delta\psi = 0.6]$