Environmental Risks and Financial Guarantees
Improving Prevention in the Mining Industry

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1. Introduction

This paper focuses on the financial guarantees that firms from the extractive industry must provide in order to start their activities, which present a risk of pollution for Society. These guarantees are used by the government at the end of the activity to finance the rehabilitation of the polluted site. Precisely, we are interested by the incentives that those guarantees yield for the firm to invest in risk-reducing activities, knowing that the remaining money after rehabilitation is given back to the firm. We are looking at the existing system and we imagine a more dynamic situation, where regular re-estimation of the guarantee deposit after audit of the environmental policy of the firm generates incentives for better prevention.

In the past two decades, the economic literature on environmental risks and their prevention has focused on extended liability (Pitchford 1995, Boyer and Laffont 1996, Anderson 1998, Dionne and Spaeter 2003), a principle that has been adopted by the US environmental policy (CERCA 1980-1985) but excluded from the new EU environmental policy. Extended liability means that the financial responsibility in the case of a polluting incident is given to the operators of the responsible firm whenever this firm cannot pay for the environmental damage. The proposed EU directive on environmental liability (COM-17, 2002) introduces a different strategy intended to ensure environmental conservation. This policy is based on the “polluter pay” principle, and on an alternative financial mechanism, namely the imposition of the financial guarantee. With this mechanism, firms - the potential polluters- are compelled to provide sufficient financial security³ for restorative activities.

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³ Performance or surety bonds, letters of credit and cash deposits are some of the possible guarantee options.
This particular mechanism would be suitable when applied to activities whose potential environmental damages entail uncertain remedial costs (Perrings 1989, Constanza & Perrings 1990). But, due to a number of drawbacks such as liquidity constraints and legal restrictions on contracts, this mechanism has not met widespread application in the field of environmental risk management (Shorgen et al. 1993). Nonetheless, for nearly three decades financial guarantees are the main economic tool used to control environmental risks generated by mining activities. The US Congress incorporated guarantees into the Surface Mining Control and Reclamation Act of 1977 (SMCRA). Over the last decade, several states added a condition related to financial guarantees to their mining legislation. The recently proposed EU directive for the management of waste from extractive industries (COM-319, 2003) has also included a provision for financial guarantees (article 14).

A mining exploitation has the specificity that it induces different types of environmental risks with potential impacts on the environment and on human health, some during the activity and others after the operating period. One most obvious impact is the change of the visual feature of the landscape, but there are also numerous other factors, such as mining waste which can cause severe hidden damage (acid rock drainage, water and soil contamination). Generally, we can separate the risks of mining activities in two classes. The first and widely known class includes risks which are associated to the productive process. In this case, the damage can be rather easily detected and restored at the end of the operation. The second class includes risks linked to events (accidents), often severe, that occur during the operative period. In both classes the remedial costs of the potential damage are uncertain and both environmental risks induce some similar impacts. If an accident occurs during the activity of the firm and if the firm is able to undertake clean-up activities, its closure cost will be technically reduced since some of the restorative activities have already been complemented.

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4 See Shorgen et al. (1993) for a detailed discussion about the elements that limit the effectiveness of financial guarantees for environmental risks.

5 The US authorities forced to adopt this measure in order to secure the ecological conservation of the mined areas and because of the countless abandoned mines.

6 Particularly, when gold and metallic minerals (e.g. iron, copper, zinc) deposits are explored.

7 Some known cases, where firms went bankrupt, are: Summitville in 1992 and Zortman and Brohm in 1998.

8 Such examples are the Anzale Ilar- Spain (1998) and Baia Mare- Romania (2001). In the first case, a dam that held tailings, collapsed and thousands tonnes of acid and metal rich water flowed out of the dam. The amount of tailings that was transported with the flood wave and that covered a large surface of the neighbouring area was estimated to be between 1.3 and 1.9 Mton. A similar accident occurred at Baia Mare gold mine and the river Dunave was polluted, causing the death of thousands of fishes with catastrophic effects on the local economy.

9 Here it is not possible for the firm to split pollution due to an accident from the one produced by the "normal" process.
The SMCRA legislation provides some fundamental measures to mitigate the environmental impacts of mining extraction but, because of several exogenous factors such as time lags, geological and hydrological features and climate conditions, it is difficult for the authorities to obtain at the beginning of the activity adequate and complete knowledge of the long term environmental risk. It is important to notice that the mean length of a mining activity is between 10 and 15 years. Furthermore, a systematic audit of all mining operations is not feasible because of their large number. Hence, incomplete information combined with limited liability creates an incentive for firms to externalize part of the environmental cost. A characteristic example is a mining firm that exploits only one deposit. If the closure liabilities exceed the project value, a “one-project-company” may prefer to be declared insolvent at the restoration stage rather than to complement the financial guaranties if not sufficient at the terminal stage of the project, where there is no prospect of a return on such an expense. Hence, bankruptcy would permit the firm to externalize the reclamation costs and, as a direct consequence, the financial burden is passed on to the authorities. Nevertheless it is reasonable to believe that firms with long-term strategy will fulfil their closure liabilities in order to keep the right to obtain new licenses for successive projects. Thus they have a strong incentive to do better prevention, aiming at a reduction of potential remedial cost. Hence attention here is focused on the “one-project-company”, namely the small and medium sized firms.

Taking risk features into account, the regulator compels the mining firms to provide, for each exploitation licence, financial guarantees for future restoration. This is known as an environmental bond because the firm will not lose more than the financial guarantee (plus the profit) at the end of the activity and it obtains the difference between the rehabilitation cost and the bond if this cost is less than the bond. The purpose of such a system is twofold: first to encourage the firm to take more preventive actions, and second, to earmark sufficient funds for restoration whenever the firm becomes either financially unable to meet its obligations of rehabilitation at the end of the activity or, prematurely during the operation, after a harsh incident.

Despite its wide use by the mining sector, there are still mixed results with regard to the effectiveness of this mechanism (Gerard, 2000). Although the phenomenon of abandoned mines has diminished, it has not disappeared\textsuperscript{10}. Moreover, in most cases\textsuperscript{11} the financial

\textsuperscript{10} The case of Pegasus bankruptcy (1998), which left back around $200 million estimated damage, raised many questions for the efficiency of the environmental bonds.

\textsuperscript{11} According to the Department of Environmental Quality, at the Summitville Mine (1992) the estimated remedying costs were about $120-150 million and the amount of financial guarantees was circa of $5 million.
guarantees were insufficient to cover the total restoration cost. We should also mention the negative effect on the insurance sector, where many insurance companies went bankrupt due to the high frequency of such cases (Shorgen et al., 1993). The inaccurate estimations of the potential risks is often due to ignorance of many parameters of the past, as well as to the lack of prevention at the early stages of projects (Muller 1998, Boyd 2001).

Furthermore, by choosing a fixed value for the bond at the beginning of the project, authorities do not offer strong incentives to firms since the financial security is not linked to their environmental performance. Taking into account that firms are protected by the limited liability rule, they have no incentive to improve the level of prevention with such a system, that means once the bond is paid. A regular re-evaluation of the bond value would provide a stronger incentive to firms to raise the expenses for preventive actions as suggested by Constanza & Perrings (1990). In this paper we examine formally this strategy and its contribution to enhancing environmental protection. We focus on a dynamic form of guarantee associated with audit that permits us to manage the moral hazard problem. In particular, we show that prevention is enhanced when firms can profit from an audit in order to announce a safe environmental policy. In addition, even if audit is costly, we state the conditions under which the expected social welfare of Society is improved without observing a deterioration of the financial condition of the firm (due to an increase in the preventive activity). We also discuss the link between the contract with re-evaluated bond we are focus on and the put and call options in finance.

The organization of the paper is as follows. Next section presents the basic model based on the existing financial guarantee mechanism, and discusses its effectiveness in a static framework. The results will be used in section 3, where the re-estimated bond is introduced and its effects on the prevention is investigated. Section 4 focuses on some comparative statics with regard to the firm’s solvency and the social welfare. Last section presents a discussion and some conclusions.

2. The model

Consider a mining firm that wants to exploit an ore-deposit. It is its sole activity, so that it will not have any revenues after the depletion of the deposit. We assume that there is no price fluctuation, thus the investment has a certain profit. Besides the extractive activity drives some environmental risks for Society. According to existing US legislation (SMCRA) and

Also, restoration costs at the abandoned Brohm mine were $53 million but the value of the environmental bond was only $29 million.
also to the forthcoming new EU legislation, in order to obtain the exploitation licence from the state, the firm is compelled to issue an environmental bond with monetary value $B$, as a financial guarantee for the potential environmental damage. For this particular model, the bond is financed out of the firm’s initial wealth $W_{12}$. The value of the bond is assessed *ex ante* by the authorities and based on the expected rehabilitation costs that will hold at the end of the activity. The bond will be released at the end of the activity if the authorities, after audit of the site, confirm that the restoration is according to the law.

Our analysis is based on a two-period model. In the first period, the extractive activity takes place and yields the certain and strictly positive profit $p_1$, while the firm bears a risk of accident $\tilde{y}$ with realizations in the bounded positive interval $[0, L]$, with $L > p_1$. This risk of accident can be mitigated thanks to risk-reducing activities; The level of prevention is denoted $e$ and defined on $[0, e^*]$, with $e^* > 0$. By denoting $F(y/e)$ and $f(y/e)$ the conditional distribution and the density function of $\tilde{y}$ respectively, we have:

**Assumption 1.** The distribution of the environmental risk $\tilde{y}$ displays the first order stochastic dominance property and is concave in prevention:

$$F_e(y/e) \geq 0, \quad F_e(0/e) = F_e(L/e) = 0 \quad \text{and} \quad F_e(y/e) \leq 0 \quad \forall y \in [0,L].$$

If $y$ is realized, either the manager is able to compensate for the damage and then he continues his activity, or his assets are not sufficient. In this situation the state confiscates them plus the part of the bond $B$ necessary for compensation and rehabilitation: the firm is bankrupted and here ends its life. If the activity stops at the end of period 1, a certain and strictly positive rehabilitation cost $d_1$ occurs, the firm forfeits the bond, which will then be used by the authorities to remedy the damage and to restore the site. It is not unfair to assume that $B > d_1$.

If the firm is able to continue its activity after having paid for $y$, it earns a certain profit $p_2$ in the second and last period and it faces the final restoration cost. The random cost of remediation at the end of the activity is denoted $\tilde{d}_2$ with realizations in $[0,D]$, $0 < D < +\infty$. Such as for $\tilde{y}$, we argue that preventive actions affect the distribution of the damage in the

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12 In real world, financial institutions usually cover partially the financial guarantees (e.g. letter of credit) for firms. Here we do not consider the relationship between the firm and the bank so that we avoid some possible chain-moral-hazard issues.
sense of the first order stochastic dominance. With \( G(d_2/e) \) and \( g(d_2/e) \) the conditional distribution and the density function of \( \tilde{d}_2 \) respectively, we have:

**Assumption 2.** The environmental risk \( \tilde{d}_2 \) displays the first order stochastic dominance property and is concave in prevention: \( G(d_2/e) \geq 0, \ G_e(0/e) = G_e(D/e) = 0 \) and \( G_{ee}(d_2/e) \leq 0 \ \forall \ d_2 \in [0, D[. \)

In this section, we consider a bond that is fixed during the whole project. Profits \( p_i \) of the firm are common knowledge, but the authorities can not observe the level of prevention \( e \) privately chosen by the firm. The sequence of the decisions is as follows: initially, the firm submits a study detailing the environmental impacts, the measures and the expected cost of restoration. Afterwards, the authorities determine the value of the environmental bond. Then, the manager selects the level of prevention \( e \) that maximizes his expected net revenue. Formally, we have:

\[
\begin{align*}
\max_{e} \quad & R = W - B - e + \int_{0}^{\pi_1} (y_1 - y_i) f(y_1/e) dy_1 + \int_{\pi_1}^{\pi_1 + B - d_1} (B + \pi_1 - y_1 - d_1) f(y_1/e) dy_1 \\
& \quad + F(\pi_1/e) \int_{0}^{B + \pi_2} (B + \pi_2 - d_2) g(d_2/e) dd_2 \\
\end{align*}
\]

(1)

The first integral represents the expected profit in Period 1 when the firm is not bankrupted, that means when profits are sufficient to cover the damage \( y \). The second integral is related to the bankruptcy states, in which the firm only obtains the remaining bond after compensation and clean up. Because of limited liability, it never looses more than the bond plus its profits. Since at least part of the bond has been confiscated, the firm can no longer continue its activity: it stops there. Hence the second period, represented by the third integral, exists only with the probability \( F(\pi_1/e) \). The level \( d_1 \) must be such that the firm does not prefer to be bankrupted at the end of the first period rather than continuing its activity. This must be true for any possible level of \( d_2 \) so that we have to impose that \( d_1 > D - p_2 \). We denote \( e^* \) the optimal solution to Program (1). It satisfies the following first order condition:

\[
1 = \int_{0}^{\pi_1 + B - d_1} F_e(y_1/e^*) dy_1 + F(\pi_1/e^*) \int_{0}^{B + \pi_2} G_e(d_2/e^*) dd_2
\]
\[ + F_e(\pi_1 / e^*) \left[ \int_0^{\pi_2} (B + \pi_2 - d_2) g(d_2 / e^*) dd_2 - (B - d_i) \right] \] (2)

It is obtained by differentiating (1) with respect to \( e \) and by using Assumptions 1 and 2 in integrations by part of the terms in \( f_e(.) \) and in \( g_e(.) \).

The left-hand-side term is the firm’s expected marginal cost of prevention and the right-hand-side is the expected marginal benefit. For both risks the firm internalizes only part of the environmental costs by considering them on the intervals \((0, p_1 + B - d_i) \) and \((0, B + p_2) \) respectively. Protected by limited liability, the manager only considers positive revenues.

Now let us define as \( e^S \) the level of prevention that is optimal for Society. In other words, under perfect information a regulator in charge of the maximization of the expected social welfare solves the following program where \( S \) is the expected social welfare:

\[
\text{Max } S = W - e + \pi_1 - \int_0^L \left[ y_1 f\left( y_1 / e \right) dy_1 - d_1 \left( 1 - F\left( \pi_1 / e \right) \right) + F\left( \pi_1 / e \right) \int_0^{\pi_2} (\pi_2 - d_2) g\left( d_2 / e \right) dd_2 \right]
\] (3)

A differentiation with respect to (w.r.t.) \( e \) and adequate integrations by part lead to the following first-order condition:

\[
\begin{align*}
e^S \text{ is such that} \\
1 = \int_0^L F_e\left( y_1 / e^S \right) dy_1 + F\left( \pi_1 / e^S \right) \int_0^D G_e\left( d_2 / e^S \right) dd_2 + F_e\left( \pi_1 / e^S \right) \left[ d_1 + \pi_2 - \int_0^D d_2 g\left( d_2 / e^S \right) dd_2 \right]
\end{align*}
\] (4)

The left-hand-side term is the social expected marginal cost of prevention and the right-hand-side term the social expected marginal benefit. They are calculated over all states of nature related to both risks, namely on \([0,L]\) and on \([0,D]\) respectively.

**Proposition 1.**

i) When the regulator is not able to observe the level of prevention chosen by the firm, the firm always chooses a level of prevention that is lower than the social optimal one.

ii) We have

\[
\frac{de}{dB} = \frac{\left[ F_e\left( \pi_1 + B - d_1 / e \right) - F_e\left( \pi_1 / e \right) \right] + F\left( \pi_1 / e \right) G_e\left( B + \pi_2 / e \right)}{|R_{ee}|},
\] (5)

which sign is undetermined. Increasing the level \( B \) of the bond may lead to decrease in prevention.

**Proof.** See Appendix. ♦
Point i) of Proposition 1 shows that even with financial guarantees, the firm chooses a level of prevention lower than the social optimum one. It is not possible to reach a first-best outcome. Point ii) permits us to go a step ahead in the discussion. Indeed it states that an increase in the level of financial guarantees will not always generate the expected effect: on the contrary, prevention may decrease. This is especially possible if the increase in the bankruptcy probability following the increase in the firm’s liability\textsuperscript{13} is sufficiently significant to induce a higher relative private marginal cost of prevention. Formally, this is illustrated by the first term at the numerator of (5): it fits with the impact of $e$ on the probability of been bankrupted at the end of the first period but with a positive remaining profit (namely for damages between $p_1$ and $p_1 + B - d_1$). Actually with $d_1 > B$ by assumption, we permit the firm to be bankrupted with a positive remaining revenue at the end of Period 1 and this mitigates its willingness to do prevention in order to increase its chances to continue. If we had $d_1 = B$, the first terms at the numerator of $de/dB$ would disappear and the ratio would always be positive. Nevertheless this effect is important since it describes a behavior that is sometimes observed in reality: the firm prefers to be bankrupted and to suffer a fair loss rather than continuing its risky activity, with chances to loose more at the end of the next period.

Finally, a mechanism with fixed bonds and no audit of the environmental policy implemented by the firm during its activity does not provide strong financial incentives for the firm to increase prevention. In the next section, we show how we can deal with these negative effects and achieve a better level of prevention by issuing re-estimated bonds.

### 3. Audit and optimal re-estimated bond contract

Now assume that the authorities have the ability to inspect the site, during the operation, and re-evaluate the restoration cost at that time. Unlike constant bond, this means that the value of the bond may be adjusted after an audit. In our two-period model, audit takes place at the end of the first period, after what the bond is re-evaluated just before the beginning of the second period. Thus, there are three options for the value of the bond: to be kept unchanged, to be increased, thus requiring the firm to add more money (from the profits of the first period), or to be decreased, so that the firm is refunded with part of the committed funds. We denote $B_i$ the bond of Period $i$ with $i = 1, 2$. The value of the bond in period 2 depends on the

\textsuperscript{13} By increasing the initial value of the bond, the authorities extends the liability of the firm. And such a scenario increases the bankruptcy probability as we show it in Section 4.
level of prevention observed by the authorities at the end of Period 1. We denote it $B_2(e)$ with $B_2'(e) < 0$ and $B_2''(e) \geq 0$. The firm’s maximization program is modified as below:

$$
\text{Max } R^e = W - B_1 - e + \int_{y_1}^{\pi_1 + \hat{a} - d_1} f \left( \frac{y_1}{e} \right) dy_1 + \int_{\pi_1}^{\hat{a} + d_1} \left( B_1 + \pi_1 - y_1 - d_1 \right) f \left( \frac{y_1}{e} \right) dy_1 \\
+ F \left( \frac{\pi_1}{e} \right) \left[ B_1 - B_2(e) + \int_{0}^{B_2(e) + \pi_2} \left( B_2(e) + \pi_2 - d_2 \right) g \left( \frac{d_2}{e} \right) dd_2 \right]
$$

(5)

By assuming that $B$ was the optimal level of bond at the beginning of the activity in the previous model, we have that

$$
\text{If } B_1 = B \text{ we have that } B_2(e) = B \text{ if } e^{\text{observed}} = e^*.
$$

(6)

With $e^*$ the solution of the previous model with fixed bond.

Compared to (1), the term $F(\pi_1/e)(B_1 - B_2(e))$ has been added at the revenue function, which describes the adjustment of the bond at the end of the first period if the firm is not bankrupted.

The optimal private level of prevention $e^p$ satisfies the following first order condition

$$
1 = \int_{0}^{\pi_1 + \hat{a} - d_1} f_1 \left( \frac{y_1}{e^p} \right) dy_1 + F \left( \frac{\pi_1}{e^p} \right) \left[ B_2(e) \left( G \left( B_2 + \pi_2 / e^p \right) - 1 \right) + \int_{0}^{B_2 + \pi_2} G_1 \left( \frac{d_2}{e^p} \right) dd_2 \right] \\
+ F \left( \frac{\pi_1}{e^p} \right) \left[ \int_{0}^{B_2 + \pi_2} \left( B_2 + \pi_2 - d_2 \right) g_1 \left( \frac{d_2}{e^p} \right) dd_2 - \left( B_2 - d_1 \right) \right]
$$

(7)

Condition (7) is obtained thanks to a total differentiation of (5) with respect to $e$, and to integrations by part of the terms in $f_1$ and in $g_1$. Now we are able to derive the following proposition.

**Proposition 2.** A bond contract that allows the authorities to audit the environmental policy adopted by the firm at the end of the period and to re-estimate the bond on the basis of this audit always leads to more prevention by the firm than a contract with standard financial guarantees.

**Proof.** Remember Property (6) and evaluate (2) and (7) at $e = e^*$. By comparing Equations (2) and (7), we observe that the marginal cost is identical, while the expected marginal benefit differs from the term $F \left( \frac{\pi_1}{e^p} \right) B_2(e) \left( G \left( B_2 + \pi_2 / e^p \right) - 1 \right)$, which is positive since $B'(e) < 0$ by assumption. Hence prevention has a higher relative expected marginal benefit for the firm in the case with re-estimation. And finally, $e^p > e^*$. ♦
In this model and contrary to the previous one, the benefit of prevention can be rather immediate for the firm since it can obtain a re-estimation of its bond after audit. Beside the improvement of the risk distribution, which only impacts the firm’s revenue in expectation, an additional effect of the risk-reducing activity appears so that the marginal benefit of them increases. Hence the optimal level of prevention increases.

Finally, by allowing the authorities to re-estimate the bond after audit, we add a dimension to the issue so that the new optimum is closer to the first best. Nevertheless, it will never achieve it because the firm’s liability is still limited although it has increased\textsuperscript{14}. Formally, this can be noticed by comparing Condition (7) to the social condition given by (4) and independent from the type of bond that is issued.

The result of proposition 2 is important because there is a significant difference between the impacts of the two options we analyze in this paper, namely between a high and constant through time bond and a system with re-estimated bonds. Indeed, in the second case, the restoration cost is expected to decrease due to better prevention. Thus a mutual fund\textsuperscript{15} may cover the extra damage if the firm is insolvent. On the contrary, in the first case the firm may prefer to avoid the improvement of the preventive activities (recall Proposition 1), because of the high value of the bond. Hence, the potential damage may be expected to be very high (catastrophic), and as a result, mutual funds or public budgets may not be sufficient to afford the necessary expenses.

Hence it seems that the authorities should encourage prevention by issuing re-estimated bonds. Nevertheless such a contract must also improve the expected social welfare of Society as a whole. This may not be the case, for instance if audit costs are prohibitive. We check this point in the next section.

4. Firm’s Solvency and Expected Social Welfare

First let us examine the effect of re-estimated bonds on the firm’s financial situation.

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\textsuperscript{14} Indeed when the firm takes back the difference between the initial bond and the new one, it holds more available assets for restoration at the end of the activity. This can be assimilated to an increase in its liability.

\textsuperscript{15} Such as the Superfund attached to the American CERCLA Legislation on waste management (1980 - 1985 - ), or such as the International Oil Pollution Compensation Fund (1969 - 1992 - ) and the American Oil Pollution Act (1990). Funds may also be publicly managed such as in France for natural disasters.
Taking into account that better prevention leads to reduction of the bond, the firm has more available assets to clean-up any damage at the end of the second period\textsuperscript{16}. Moreover, prevention affects the loss distribution and as a consequence the gross profit distribution. Thus, re-estimated bond have two effects on the firm’s probability of bankruptcy: a direct effect in the second period and an indirect one in the first period. In the meantime, increasing prevention is also costly. The total impact is described in the proposition hereafter.

**Proposition 3.** A re-estimated bond contract yields a bankruptcy probability that is *almost always* less than that obtained in the standard model.

**Proof.** The probability of bankruptcy is \(1 - F(\pi_1 / e)G(\pi_2 + B_2(e) / e)\).\textsuperscript{17} Thus:

\[
\frac{d}{de} \left[ 1 - F(\pi_1 / e)G(\pi_2 + B_2(e) / e) \right] = -\left[ F_e(\pi_1 / e)G(\pi_2 + B_2 / e) + F(\pi_1 / e) \left( G_e(\pi_2 + B_2 / e) + B_2'(e) \cdot g(\pi_2 + B_2 / e) \right) \right]
\]

By definition, \(F_e(\pi_1 / e)\) and \(G_e(\pi_2 + B_2(e) / e)\) are positive, while \(B_2'(e)\) is negative. Knowing that we are working with continuous intervals of variation for the random variables and with general distributions, it is realistic to assume that \(g(\cdot)\) is small so that this derivative is *almost always* negative. From Proposition 2 we also have that any re-estimated bond contract yields a higher level of prevention from the firm, we conclude that such a contract leads to a decrease in the bankruptcy probability.

Q.E.D.

The re-estimated bond contract mitigates the firm’s probability of bankruptcy if the decrease in the bond level after audit (assuming that a decrease in the bond takes place) does not induce a too strong decrease in the available assets of the firm (recall that the available assets are equal to the profit plus the bond). It is important to notice that a deterioration of the financial condition of the firm is not necessarily a bad thing for it because it contributes to limit its ex post liability. On the other hand, it is always a bad thing for Society. Hence we have now to

\[\text{In the case of the Summitville Mine the authorities compelled the firm to increase the value of its bond, this during a difficult period, thus reducing in fact the financial resources, and as a direct result, contributing to a declaration of insolvency.}\]

\[\text{\textsuperscript{16} F(\pi_1 / e)G(\pi_2 + B_2(e) / e) is the probability of being solvent at the end of Period 2. It is conditioned by the fact that the firm must be solvent at the end of period 1, namely that } y \leq \pi_1.\]
examine the benefits of a re-estimated bond contract for Society. In the case where the reduction of the bond is very large (for instance if $B$ is particularly sensitive to a variation of $e$), the secured funds may be insufficient to cover the cost of reclamation if the firm declares insolvency. Hence, the impact of a decrease in the bond value must be counterbalanced by the positive effects on prevention.

Assume that the authorities have to pay a fixed amount $A$ for each inspection of the site at the end of the first period. The function of the expected social welfare is now:

$$S^a = W - e + \pi_1 - \int_0^L y_1 f \left( \frac{y_1}{e} \right) dy_1 - d_1 \left( 1 - F \left( \frac{\pi_1}{e} \right) \right) + F \left( \frac{\pi_1}{e} \right) \int_0^B \left( \pi_2 - d_2 \right) g \left( \frac{d_2}{e} \right) dd_2 - A$$

(8)

Notice that $S^a$ is equal to $S$, the expected social welfare in the standard model, plus the audit cost. The structure of the bond contract has no direct effect on the expected social welfare: neither $B$ nor $B_2$ enter directly the equation. It influences it only through its impact on $e$.

**Proposition 4.** There exists a level $\bar{A}$ strictly positive such that for any audit cost less than $\bar{A}$, a re-estimated bond contract yields always a higher expected social welfare.

**Proof.** See Appendix.

The result of proposition 4 is rather intuitive. Indeed if auditing is too costly for Society, it may not benefit from the re-estimated bond contract even if it always induces more internalisation by firms of the environmental risk. Nevertheless, recall that in our model we assumed that audit is systematic, thus it holds at the end of Period 1 with probability one.

There exist several papers in different fields (Picard 1996, 2000; Mookherjee and Png 1990, 1992; Shapiro and Stiglitz 1984) that show that it is not necessary to announce systematic audit in order to induce agents to take the adequate action. Actually, it is sufficient to announce a credible audit policy that will occur with some positive probability. The threat of being controlled or, as in our model, the hope of being audited in order to obtain a reduction in the bond level, may be sufficient for firms to invest in risk-reducing activities. Hence it would be interesting to consider re-estimated bonds in an economy with random audit. The optimal probability of audit would be the one that yields the right level of prevention knowing a given norm of environmental quality to be achieved.
4. Conclusion

By compelling a mining firm to provide an environmental bond before starting its activities, the authorities ensure funds to cover clean-up and compensation activities, in the event where the firm becomes financially unable to meet its obligations. Even though this mechanism was introduced with the intent to improve the level of environmental prevention, its first effect is that an increase in the firm’s partial liability. Elements from the US mining industry indicate that many sites are still abandoned and moreover that the amount of the bonds are usually insufficient to cover the whole restoration cost. In this paper we have explored two options of financial guarantees: a) the first contract displays a fixed \textit{ex ante} value of guarantees for the whole period of activity and b) the second one displays a bond that is re-evaluated after audit of the environmental measures adopted by the firm.

In the first model, with a fixed bond, we showed that firms does not always have incentives to implement better prevention. Furthermore, the probability of bankruptcy is affected by the magnitude of the bond, so that the latter determines the firm’s assets available for clean-up and compensation. Precisely, an increase in the level of the bond deteriorates the financial condition of the firm and it may be reluctant to invest more in prevention. Thus, the only sure effect from the environmental bond is that it increases the firm’s participation in the rehabilitation expenses at the end of the activity.

The re-estimated bond contract that is proposed in the second part of the paper may improve the level of prevention. Aiming on a future reduction of the bond, the manager is interested by a higher level of prevention. On the other hand, the firm faces the risk to be compelled to lock up more assets for the bond if the updated restoration cost is increased. This scenario has a “negative” effect on the probability of bankruptcy. Thus, instead of locking up more funds in the bond, the manager prefers to pay for better prevention and, as a result, to increase his expected revenue by mitigating the environmental risks.

Given that financial guarantees were introduced as the major financial tool to the EU environmental policy, it is very interesting to examine our theoretical framework in the spirit of what is done in practice. In our model, we assumed that the firm covers itself the value of the bond from its initial wealth. In practice the financial institutions play a significant role as a third part guarantor. If providing the necessary financial certifications, firms can meet their obligations sometimes at a fair cost. Hence an extension of this model would be to consider the participation constraint of the bank. This would make the level of the bond depend not only from the level of prevention but also from pure financial considerations, such as the free interest risk, the risk of default, etc.
Furthermore, in the perspective of adopting the mechanism of financial guarantees in the new EU directive on waste management in the extractive industry, it might be appropriate to consider the implementation of the re-estimated bond contract as a way to increase the incentives for the mining firms to enhance prevention.

Our analysis is based on a simple two period model. As a next step, it would be interesting to add other periods to the model. In doing so, we would be able to analyze the manager’s behaviour in sequential stages, since he has incentives in each stage, thus giving a more dynamic dimension to this issue.

Discussion about the link between our results and the theory of options in finance (put, call, …). TO BE DONE.

APPENDIX

Proof of Proposition 1.

Point i).

In Equations (2) and (4), the marginal costs are identical and equal to 1, while the expected marginal benefit in (2) is calculated over \([0, \pi_1 + B - d_1]\) and \([0, B + \pi_2]\), while it is evaluated in (4) over all states of nature. Hence the expected marginal benefit is less in (2) than in (4), and we have in optimum that \(e^S > e^*\).

Point ii).

A total differentiation of (2) with respect to \(e\) and \(B\) yields:

\[
R_{ee} de + \left[ F_e(\pi_1 + B - d_1/e) - F_e(\pi_1/e) + F(\pi_1/e)G_e(B + \pi_2/e) \right] dB = 0
\]

\[
\Leftrightarrow \frac{de}{dB} = \frac{F_e(\pi_1 + B - d_1/e) - F_e(\pi_1/e)}{-R_{ee}} + \frac{F(\pi_1/e)G_e(B + \pi_2/e)}{R_{ee}}
\]

with \(R_{ee}\) being the second derivative of \(R\) defined by (1). From the second order condition, \(R_{ee}\) is negative so that we obtain the ratio of Point ii) in Proposition 1. The first term at the numerator is always negative because \(d_1 \leq B\) and \(F_e(.) \leq 0\) by assumption.

Q.E.D.

Proof of Proposition 4.
With $S^e = S - A$, we have that
\[
\frac{dS^e}{dB} = \frac{dS}{de} \cdot \frac{de}{dB}.
\]
With $e^S$ the social optimum, we also have that $\frac{dS^e}{de|e^S} = 0$ and $\frac{dS^e}{de|e^* < e^S} > 0$. Given that $\frac{de}{dB}$ is negative, we obtain that $\frac{dS^e}{dB} \leq \forall e^* \leq e^S$. Thus, if the re-estimated bond contract induces a decrease in the bond after audit, it improves the expected social welfare compared to the fixed bond if the audit cost is nil. For any positive audit cost, the effect must be sufficient to absorb it, so that re-estimated bond contracts are optimal if the audit cost is less than a given positive scalar $\bar{A}$.

Q.E.D.

References


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COM(2002)/17. Proposal for environmental liabilities


