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Environmental Auditing in Management Systems and Public Policy[1]

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ABSTRACT

New international standards for environmental auditing are now being actively promoted by public authorities and adopted by private firms. One important feature of these standards is their emphasis on managerial systems and incentives that support a wiser use of environmental resources. This paper studies such a system, in which incentive compensation may be based in part on the results of an environmental audit. It is found that optimal wages after an environmental audit is performed should have a greater range than wages paid when no audit has occurred. It is also shown that the decision to conduct an environmental audit and the size of the expected wage in this case depend crucially on whether the agent's prudence (or precautionary motives) dominates or not his aversion to risk. It is finally found that the insertion of environmental audits within current management systems would certainly induce a manager to care more about the environment; although this may come at the expense of less concern for other activities, we find plausible circumstances in which properly designed environmental audits overcome such a tradeoff and increase the manager's attention to *both* environmental and traditional tasks. Some implications of the analysis for environmental public policy are also discussed briefly.

Key words: Multi-task principal-agent analysis, environmental auditing, risk aversion, prudence.

JEL classification numbers: D82, L15, M49

1. INTRODUCTION

"What you don't know will hurt you."
[*F. Friedman, Vice-President, Occidental Petroleum Corporation, in a speech to the Chemical Manufacturers' Association,* 1983]

Since its first (mandatory) introduction in the US chemical and steel industries in the late 1970s, environmental auditing has become a major tool for the management of environmental resources [6, 13, 14, 25]. Nowadays, environmental audits are being routinely conducted within companies to define the extent of their liabilities towards the environment, to check compliance with environmental legislation, to test newly acquired land or buildings, and to assess environmental risks, employees' safety, energy consumption, waste streams or pollutant emissions [7, 17]. Yet, despite its widespread use, environmental auditing remains an evolving discipline. It seems quite likely that its practice will change significantly in the near future. This assertion is based on the recent development, and active promotion by public authorities, of international standards for the practice of environmental audits and the certification of environmental auditors [5, 8, 9, 10].[2]

[2] Auditing has been a key tool of the financial accounting profession for many years. As far as the environment is concerned, however, audits began to appear only in the late seventies in large US firms such as US Steel (in 1977), Allied Chemical (in 1979), General Motors and ARCO, as a response to rising environmental worries (see [17]). In the 1980s, the practice of environmental auditing spread further, particularly across the chemical industry, under the public and regulatory impact of the Bhopal disaster and new insurance contracts linking insurance fees to environmental risks and pollution. In 1988, the US and Canadian Chemical Industry Associations jointly adopted the Responsible Care Programme, which was the first significant multi-firm initiative that specified environmental audits. Those audits, however, sought primarily to check compliance with environmental regulations and their results were intended for a company's eyes only. Moreover, although the Responsible Care Programme noted the value of audits as a tool for management evaluation and supervision, environmental auditing was generally not integrated with any management control system [see 35].

By the early 1990s, company environmental audits were becoming quite common, and the International Chamber of Commerce (ICC) had started to promote them. According to the ICC [20]: "[An environmental audit is] *a management tool* comprising systematic, documented, periodic and objective evaluation of how well environmental organization, management and equipment are performing, with the aim of helping to safeguard the environment by *facilitating management control of environmental practices* and assessing compliance with company policies, which would include meeting regulatory requirements." At the time of this statement, a drive for quality was transforming industry. International quality management norms, such as the ISO 9000 which sets up quality audits, were gaining worldwide acceptance. In this context, the British Standard Institute published in 1992 the first standard - the BS 7750 - for a management system incorporating environmental auditing. ISO itself made a proposal for an international standard of corporate environmental management at the Rio de Janeiro 1992 Earth Summit. This lead to an update of current ISO norms - the ISO 14000 - which includes requirements for environmental management and auditing. On April 10, 1995, Typical of these new standards is their emphasis on so-called "environmental management systems", i.e. the way business and industry are structured to address environmental, health or safety compliance and risk, and also their insistence on integrating such systems within mainstream management procedures. The influential International Organization for Standardization (ISO), for instance, stipulates in its new ISO 14000 standards that "a firm must set up and maintain programmes and procedures for periodically holding audits of its environmental management system", whilst being able at the same time "to integrate environmental management with its general systems for implementing strategic plans."[3] These requirements raise a number of issues. Obviously, there is the matter of fit of environmental auditing with concrete management systems such as financial appraisal and bonus calculation. This matter remains relatively unexplored, despite its being crucial if the new (tougher) standards for environmental auditing are to be adopted *voluntarily* by industry. A related and key question is the impact on business decision-making of carrying out environmental audits according to the new norms. These issues are the topic of this paper.

At this point, given the relatively short history of environmental auditing and the consequent scarcity of data, we must rely on formal analogies and theory to address them. An obvious starting point is the extensive theoretical literature on corporate audits, which is based on the principal-agent model. This literature distinguishes two kinds of audits: those aiming to verify a declared outcome, for example an announced return [27, 34], and those that provide information on a key input, for

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the European Commission (EC) announced the implementation of its so-called Eco-Management and Audit Scheme (EMAS). It is now part of the Commission's environmental policy apparatus, and some firms have already won registration under it.

[3] These statements, drawn from [2], correspond to articles 4.4.4 and 4.2.4 of ISO 14001.

example the agent's effort [1, 12]. The actual philosophy of environmental auditing seems to favor the latter kind [see 2, 33]. Our model will therefore be similar to the one used by Baiman and Demski [1]. There is one major difference, however. The matter here is not so much the total amount of effort that the agent delivers, but rather the *allocation* of this effort between environmental and non-environmental tasks. So building on recent studies [3, 4, 19] and our earlier work [15], we use a *multi-task* principal-agent model. In such a model, the agent must allocate effort between, say, a financial task and an environmental task.[4] This allocation cannot be observed by the principal who can only infer the agent's effort from some imperfect measure of performance on each task. Previous models of this sort assumed costless and constant monitoring of the variables of interest - the agent's effort on each task. In reality, every monitoring system is costly, and the principal may decide against constant monitoring. In this paper, we suppose therefore that financial performance is always monitored, but we endogenize the principal's decision to audit the agent's degree of environmental diligence.

The model provides new insights for the management integration of environmental auditing. One first result is that optimal wages after an environmental audit is performed should have a larger range than wages paid when no audit has occurred. A second finding is that in this context the agent's allocation of effort is essentially determined by whether his prudence is stronger or weaker than his aversion to risk; hence, the relationship between these two features of the agent's behavior

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[4] The name "multi-task principal-agent problem" might leave the impression that the agent is actually performing several different assignments simultaneously, which he is not. An example of what we have in mind here is, for instance, a project evaluator who might be more or less careful in assessing the environmental impact of a proposal along with its financial prospects. John Hartwick suggested that we rather call the problem a "multi-*impact* principal-agent problem". Indeed, this describes better the generic situation that we model. We will keep using the previous name, however, only to remain consistent with the literature.

will guide the optimal design of environmental audits.[5] When prudence dominates, for instance, it is better to run an environmental audit if current profits are high and to offer the agent a larger expected wage each time an audit takes place. Concerning the impact of environmental audits on business decision-making, the model also indicates that the insertion of environmental audits within current management systems would certainly induce the agent to care more about the environment. Whilst this may come at the expense of less concern for non-environmental activities, we find plausible circumstances in which optimal environmental audits overcome this tradeoff and induce the agent to increase his attention towards *both* environmental and non-environmental tasks. The intuition for this result is straightforward when the agent's prudence dominates his aversion to risk. In this case, the agent wishes to be audited, and of course that the audit result be a good one. Hence, the agent would tend to work harder on financial tasks, in order to make high profits more likely, as well as on environmental tasks, in order to increase the probability that the conclusion of an environmental audit be favorable.

The paper is organized as follows. Section 2 presents the multi-task principal-agent model. Section 3 states and discusses the results. Section 4 contains conclusions and remarks for environmental public policy.

2. THE MODEL

The introduction of environmental audits in a firm can be viewed as an amendment to current

[5] Prudence refers to "the propensity to prepare and forearm oneself in the face of uncertainty, in contrast to risk aversion, which is how much one dislikes uncertainty and would turn away from uncertainty if possible" [24, p. 54]. In our multi-task setting, prudence entails that the agent would shelter against risk by choosing an allocation of his effort that increases his average income, whilst risk aversion implies that the agent would rather tend to distribute his effort in order to lower the probability of occurrence of the worst outcome.

management information systems. Since Holmström's [18] seminal work (see also Kim [23]), formal economic studies of such systems have been done using principal-agent modelling. Although these studies were prompted by problems specific to the fields of accounting and corporate finance, direct analogies can now be made between financial and environmental audits. Indeed, the widespread adoption of publicly-endorsed international norms of environmental auditing should make it possible to draw explicit contracts that make compensation contingent on environmental performance. This supports the modelling approach that follows.

Consider a one-period principal-agent relationship in which the agent must split his effort between "standard" business activities and environmental protection. Let the amount of effort spent on those activities and the environment be denoted by x and y respectively. The agent can vary both his total effort and the allocation of that effort between the two tasks. The principal can observe neither the agent's total effort nor its allocation; she can, however, receive estimates π and ϵ of, say, the revenues generated and the environmental costs reduced by the agent's effort level and allocation. Those estimates are drawn from a finite subset of real numbers according to the information technology $g(\pi,\epsilon * x,y)$.[6] We make the following standard assumptions about g.

ASSUMPTION 1: $g(\cdot * x,y)$ is strictly positive on its domain, for all x, y. At each vector (π,ϵ), it is twice continuously differentiable in (x,y).

Effort on standard business duties is easily and routinely monitored through the firm's current financial reporting system. By contrast, whether and how much the agent keeps an eye on the

[6] Assuming that the set of signals is finite instead of continuous does not bear any consequences on results. It just simplifies the exposition.

environment is costly to assess directly, so environmental audits may be infrequent. On the basis of the information available *(π)* from financial monitoring, the principal may audit the agent with probability *$m(\pi)$*. If an environmental audit is done, a fixed cost *K* is incurred and the estimate ϵ, which can be positive or negative, is received. The principal's estimate of expected total revenue, noted *$R(\pi,\epsilon)$*, increases with π and ϵ.[7]

In order to facilitate the analysis, we now suppose that the signals π and ϵ are independent *conditional* on knowing the chosen effort levels *x* and *y*. The information technology *g* will moreover be viewed as the product of two disjoint likelihood functions.

ASSUMPTION 2: $g(\pi,\epsilon|x,y) = f(\pi|x)\, h(\epsilon|y)$.

This assumption is less restrictive that it seems. It does not imply, for instance, that nothing can be inferred about *y* or ϵ from observing only π (or even *x*), because *x* and *y* are linked through the agent's disutily of effort (see assumption 3 below).[8] It says, however, that the information ϵ gathered through environmental auditing will be quite complete and will render previous information π redundant for assessing the amount of effort *y* devoted to environmental protection. Technically (see DeGroot [11] for definitions), assumption 2 implies that ϵ is a *sufficient statistic* in this model, as far as *y* is concerned (and so is π with respect to *x*). This seems consistent with the exhaustiveness

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[7] This way of expressing the principal's revenue allows for representing many sorts of interactions between this revenue, the financial assessments π, and the appraisals ϵ of environmental care.

[8] To be consistent with the model (and the equilibrium), the principal's prior probability *$p(x,y)$* that the agent chooses effort vector *(x,y)* will then have to be nonseparable. According to Bayes's rule the principal's updated probability of *(x,y)* after observing π will be given by

$$g(x,y\,|\,\pi) = \frac{p(x,y)\,f(\pi\,|\,x)}{\sum_x p(x)\,f(\pi\,|\,x)} \quad , \quad \text{where } p(x) = \sum_y p(x,y) \quad .$$

objective of environmental auditing [2].

The principal is assumed to be risk neutral. The agent's behavior fits the following assumptions.

ASSUMPTION 3: The agent has a utility $U:(\underline{z},\infty)\rightarrow\mathbb{R}_+$ for money that is strictly increasing, continuously differentiable, strictly concave (i.e. exhibits strict risk aversion). An effort vector *(x,y)* costs the agent *C(x+y)*, where the function $C:\mathbb{R}_+\rightarrow\mathbb{R}_+$ is increasing, convex and twice continuously differentiable. C(0) = 0, C'(0) = 0, and C'(∞) = ∞.

The first part of assumption 3 is a standard one. The second part means that there are decreasing returns to *total* effort, but that the agent is indifferent *ex ante* between spending effort on regular activities or on environmental protection.[9]

The principal can now offer the agent a contract that includes the possibility of an unannounced environmental audit and that makes the paid wage in this case contingent on audit results. How frequently, or whether, audits are actually done under this contract is a discretionary decision of the principal, to which she can commit. There are economic constraints on such a contract, however. First, it must provide the agent with a utility at least equal to his reservation utility U^*, so that the agent would voluntarily accept the contract; this is the so-called *individual rationality* or participation constraint. Second, it must take into account the fact that the agent will set his effort level and allocation in order to maximize his own utility; this is the *incentive compatibility* constraint. Let $s(\pi)$ denote the agent's wage when only the estimate π is gathered, and $w(\pi,\epsilon)$ be the wage if there is an environmental audit. The optimal contract will then be a solution

[9] The principal's risk neutrality and the agent's indifference between tasks are not crucial assumptions, but they again ease the analysis significantly.

to:

$$\max_{w,s,m,x,y} \sum_{\pi,\varepsilon} [m(\pi)(R(\pi,\varepsilon) - w(\pi,\varepsilon) - K) + (1-m(\pi))(R(\pi,\varepsilon) - s(\pi))]\, g(\pi,\varepsilon \mid x,y)$$

$$subject\ to$$

$$(x,y) \in \arg\max_{x,y} \sum_{\pi,\varepsilon} [m(\pi)U(w(\pi,\varepsilon)) + (1-m(\pi))U(s(\pi))]\, g(\pi,\varepsilon \mid x,y) - C(x+y) \qquad (1)$$

$$\sum_{\pi,\varepsilon} [m(\pi)U(w(\pi,\varepsilon)) + (1-m(\pi))U(s(\pi))]\, g(\pi,\varepsilon \mid x,y) - C(x+y) \geq U^*$$

This is a typical principal-agent problem with multiple tasks and signals. An additional decision variable for the principal here is *m(*π*)*, the probability of auditing the agent after π is observed.

The first-order approach

The incentive compatibility constraint of problem (1) is rather complex: it hides a continuum of inequality constraints. To make the problem tractable, one may replace it by (an approximation of) the first-order necessary conditions for having a stationary point of the agent's expected utility. This leads to the modified problem:

$$\max_{w,s,m,x,y} \sum_{\pi,\varepsilon} [m(\pi)(R(\pi,\varepsilon) - w(\pi,\varepsilon) - K) + (1-m(\pi))(R(\pi,\varepsilon) - s(\pi))]\, g(\pi,\varepsilon \mid x,y)$$

$$subject\ to$$

$$\sum_{\pi,\varepsilon} [m(\pi)U(w(\pi,\varepsilon)) + (1-m(\pi))U(s(\pi))]\, g_x(\pi,\varepsilon \mid x,y) - C'(x+y) \geq 0$$

$$\sum_{\pi,\varepsilon} [m(\pi)U(w(\pi,\varepsilon)) + (1-m(\pi))U(s(\pi))]\, g_y(\pi,\varepsilon \mid x,y) - C'(x+y) \geq 0 \qquad (2)$$

$$\sum_{\pi,\varepsilon} [m(\pi)U(w(\pi,\varepsilon)) + (1-m(\pi))U(s(\pi))]\, g(\pi,\varepsilon \mid x,y) - C(x+y) \geq U^*$$

The approach that consists in solving this problem instead of problem (1) is called the *first-order approach*. What matters of course is that all solutions to problem (2) be also solutions to problem (1). It can be shown that this is the case under the next assumptions, provided the solution $m(\pi)$ increases with π (see [30]).

ASSUMPTION 4: [Monotone likelihood ratio property] The ratios $f_x(\pi * x)/f(\pi * x)$ and $h_y(\epsilon * y)/h(\epsilon * y)$ are nondecreasing in respectively π and ϵ, for every vector (x,y).[10]

ASSUMPTION 5: [Monotonicity and convexity of the distribution function] The upper cumulative probability distributions $\sum_{(\pi,\epsilon) > (\underline{\pi},\underline{\epsilon})} g(\pi,\epsilon | x,y)$ are increasing and concave in (x,y).

ASSUMPTION 6: The first two constraints of problem (2) are *both* either strictly binding or nonbinding (i.e. their respective associated multipliers have the same sign).[11]

We could not find general assumptions that guarantee the validity of the first-order approach if the optimal auditing probability $m(\cdot)$, which is an endogenous variable in this model, turns out to be a decreasing function. Let us simply assume that the parameters of the present model are such that the approach still yields correct solutions in this case.

This completes the description of the model. We shall now turn to the derivation and discussion of results.

3. RESULTS

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[10] The subscripts $_x$ and $_y$ denote partial derivatives with respect to x and y respectively.

[11] Note that this assumption can easily be made to hold by a slight perturbation of the relevant parameters in the contraints.

We have raised several questions concerning the integration of environmental auditing within mainstream management systems. We will now try to answer those questions using the above principal-agent model. The first subsection explores the possible use of environmental audits as an input for incentive compensation. The second subsection studies the optimal occurrence of environmental audits. The third and last subsection focuses on the resulting effort allocation chosen by the agent. In order to make the paper self-contained, mathematical proofs of the results have been put in an appendix.

Environmental audits and incentive compensation

A key role of management systems is to align employees' private objectives with those of the firm. Increased environmental awareness on the part of shareholders and corporate board members

will not change the firm's environmental record in a significant and durable way unless it is translated into concrete amendments of the existing managerial system. In many firms, an important component of such a system is incentive pay which varies wages according to measured performance. This subsection formally investigates how incentive pay should be modified to incorporate the assessments of environmental care that come from environmental audits.

In the present framework the incentive wage schedule that is put in place by the principal would satisfy the first-order necessary conditions for an optimum of problem (2). Let γ, λ, δ be the Lagrange multipliers attached to the first, second and third constraint of (2) respectively. (Note that, these contraints being inequalities, their associated multipliers can and will always be made nonnegative in the expressions below.) The first two multipliers, γ and λ, are the shadow prices of the incentive compatibility constraints on efforts *x* and *y* respectively. They measure the increase in the principal's profit resulting from a marginal deviation by the agent from his utility-maximizing effort on standard and environmental activities respectively. The third multiplier, δ, is the shadow price of the participation constraint, which captures the increase in the principal's profit from a marginal decrease in the agent's reservation utility, U^*. The necessary conditions for *s* - the incentive wage if no environmental audit occurs - are now:

$$\forall\pi:\ (1-m)\sum_{\epsilon}\left[-fh+\gamma U'(s)f_x h+\lambda U'(s)f h_y+\delta U'(s)fh\right]=0 \qquad (3)$$

Those conditions for *w* - the incentive wage when an environmental audit is held - are:

$$\forall(\pi,\epsilon):\ m\left[-fh+\gamma U'(w)f_x h+\lambda U'(w)f h_y+\delta U'(w)fh\right]=0 \qquad (4)$$

Equations (3) and (4) yield the following respective conditions:[12]

$$\forall\pi:\quad \frac{1}{U'(s(\pi))}=\delta+\gamma\frac{f_x(\pi;x)}{f(\pi;x)}\ ,\ \ and \qquad (5)$$

$$\forall(\pi,\epsilon):\quad \frac{1}{U'(w(\pi,\epsilon))}=\delta+\gamma\frac{f_x(\pi;x)}{f(\pi;x)}+\lambda\frac{h_y(\epsilon;y)}{h(\epsilon;y)}\ . \qquad (6)$$

A key relationship between $s(\pi)$ and $w(\pi,\epsilon)$ can now be derived from the above equations. Substracting (6) from (5), one gets

[12] Note that, since $\Sigma_\epsilon\, h \equiv 1$, then $\Sigma_\epsilon\, h_y \equiv 0$ and $\Sigma_\epsilon\, f\, h = f$. Equations (5) and (6) must clearly be satisfied when $0 < m(\pi) < 1$, and can be made to hold as well whether $m(\pi) = 1$ or 0.

$$\forall(\pi,\epsilon): \quad \frac{1}{U'(s(\pi))} - \frac{1}{U'(w(\pi,\epsilon))} = -\lambda_y \frac{h(\epsilon, y)}{h(\epsilon^*, y)} \, . \qquad (7)$$

In the results that follow, much bears on whether 1/U' - the multiplicative inverse of the agent's utility function - is convex or concave. Convexity of 1/U' obtains when $-2(U''/U') \geq -U'''/U''$, and concavity results under the reverse inequality. The ratio $-U''/U'$, which will be referred to as *A*, is the well-known coefficient of absolute risk aversion, which captures the agent's willingness to avoid risk. The ratio $-U'''/U''$, on the other hand, is called the *index of absolute prudence* and will be denoted accordingly as *P*; it captures the strength of the agent's *adjustment* to risk or precautionary motives. There is a close analogy between *A* and *P* in the following sense (see Kimball [24]): whilst at each point the former indicates the size of equivalent risk premia, or the maximal amounts that the agent would consent to give up in order not to face some 0-expected-payoff lotteries, the index *P* relates to the size of *equivalent precautionary premia*, i.e. the certain reductions in current wealth that would have the same effect on the agent's *decisions* as the introduction of some 0-expected-payoff lotteries.[13] The relative magnitudes of *A* and *P* have recently been shown to play an important part in many situations sequential risks (see Gollier and Treich [16]). Its intuitive role in the present context will become clearer in the next subsection, after we have discussed both incentive compensation and the optimal occurrence of environmental audits.

Let us now state some general characteristics of the optimal wage schedule.

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[13] Formally, let k be the agent's current wealth, θ a random variable with 0 mean, and **E** the expectation operator. The equivalent risk premium α for θ and k is defined by $\mathbf{E}U(k+\theta) = U(k-\alpha)$, whilst the equivalent precautionary premium β for θ and k must satisfy $\mathbf{E}U'(k+\theta) = U'(k-\beta)$. The β's can therefore be measured in a manner similar to the α's.

PROPOSITION 1. *Under the above assumptions, $s(\pi)$ and $w(\pi,\epsilon)$ have the following properties:*

(i) *s and w are nondecreasing in their respective arguments.*

(ii) *$s(\pi) \geq w(\pi,\epsilon)$ when ϵ is small and $s(\pi) \leq w(\pi,\epsilon)$ when ϵ is large.*

(iii) $\forall\pi: \sum_{\epsilon} w(\pi,\epsilon)h(\epsilon|y) \geq (\leq) s(\pi)$ *if* $2A \leq (\geq) P$.

The first part of the proposition is unsurprising: wages should rise with better signals on the regular or the environmental tasks. A more interesting statement is (ii), which says that the wage range under an environmental audit spans the wage range without one. Hence, an agent may be either better or worse paid after an environmental audit occurs: the wage gradient becomes steeper in this case and the agent is bearing more risk. Statement (iii) adds, furthermore, that the relative magnitude of *A* and *P* determines whether the expected wage after an audit occurs is larger or smaller than the wage when no audit takes place.

On the optimal occurrence of environmental audits

The main difference between monitoring and auditing is that the latter's occurrence is contingent on specific events that can be chosen strategically by the principal. By selecting the levels of the standard business indicatorπ that trigger an environmental audit, the principal can influence the agent's allocation of effort in order to raise expected profit. The agent's reaction to the threat of audits will in turn depend on some characteristics of his utility function. According to the following proposition, only two such characteristics - prudence and risk aversion - need to be considered in order to design an optimal auditing policy.

PROPOSITION 2: *Provided K is not too high,* $m(\pi) > 0$ *under the following circumstances:*

(i) when π *is small, if* $2A > P$;

(ii) *when* π *is large, if* $2A < P$ *and the agent's aversion to risk is small.*[14]

The intuition behind propositions 1 and 2 can now be explored. When $2A \geq P$, the agent's risk aversion is "high enough", so that he would mainly try to avoid the worst outcome of an environmental audit, which is getting paid a low wage $w(\pi,\epsilon) < s(\pi)$ after a small estimate ϵ of environmental diligence is observed. This implies that the agent might spend too much effort on environmental protection, at the expense of standard business activities. One obvious way for the principal to restore a balance is to worsen the outcome associated with a poor assessment π: she will then run an environmental audit when π is low and decrease the agent's expected wage in this case. If $2A < P$, on the other hand, the agent's precautionary motives "dominate" his aversion to risk. This means that the agent will seek not so much to avoid the bad outcomes associated with an environmental audit, but rather to increase his income considering the possibility of such an audit. This income increases in π, so this time the agent might care too much about standard business tasks at the expense of the environment. One way for the principal to fix this is to conduct environmental

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[14] The conditions of the proposition can actually be made sharper (see the remark in the appendix). Baiman and Demski [1] assume that the agent's utility function belongs to the HARA family, which includes utility functions with constant, increasing or decreasing absolute or relative risk aversion, and state propositions 1 and 2 referring to the parameters of the agent's utility function instead of comparing the index of prudence with the coefficient of absolute risk aversion. For instance, if the agent's utility function exhibits constant *relative* risk aversion, i.e. the agent's utility is of the form $U(z) = (\alpha/(1-\alpha))(z/\alpha)^{1-\alpha}$ where the coefficient of *relative* risk aversion, defined as $-zU''(z)/U'(z)$, is precisely α, then $2A$ is less than, equal to, or greater than P whenever α is less than, equal to, or greater than 1. This "parametric" approach, however, in addition to giving slightly less general results, does not contribute much to an understanding of the agent's *effort allocation* incentives.

audits when π is high, and to mitigate the agent's prudence by increasing his expected wage when an audit takes place.

The latter situation seems to agree better with common sense and casual observation. For it seems more plausible that business firms would deem environmental negligence to be likely, and would therefore conduct an environmental audit, when they get unusually optimistic short-term financial assessments. This belief is actually not inconsistent with the widely accepted assumption that absolute risk aversion is decreasing. To see this, first note that

$$\frac{A'(z)}{A(z)} = \frac{d}{dz}\ln\left(\frac{-U''(z)}{U'(z)}\right) = \frac{U'''(z)}{U''(z)} - \frac{U''(z)}{U'(z)} = A(z) - P(z)\ . \qquad (8)$$

If absolute risk aversion decreases, we have that $A < P$. If it decreases at a sufficiently high rate, we get $2A < P$, and the intuitive scenario unfolds by the above propositions.

Environmental audits and effort allocation

A contract that includes the possibility of environmental audits raises the principal's cost in two ways compared with a contract without any audits. First, it entails the direct cost of the audits; second, it may raise the expected wage cost. Offsetting this, however, is the increase in revenue that might come from stronger incentives and a better reallocation of the agent's effort which the threat of audits induces. The next proposition makes this statement precise.

PROPOSITION 3. *The introduction of environmental audits brings an increase in the agent's* *effort y directed at the environment. Moreover, if* 2A $\geq$ P, *or if* 2A < P *and the agent is not too risk averse, a positive probability of an environmental audit also induces an increase in the effort x spent on standard business tasks.*

According to this proposition, the amounts of effort devoted by the agent to standard duties and to environmental protection can become *complementary* arguments of the agent's utility under an optimal audit policy. This is a striking result, given that the agent was assumed to be indifferent *a priori* between working on standard tasks versus environmental protection (*x* and *y* are *substitutes* in the agent's cost function). It has an intuitive rationale, however. Since $s(\pi) > w(\pi,\epsilon)$ when ϵ is small but $s(\pi) < w(\pi,\epsilon)$ when it is large (proposition 1), the agent will always increase the effort *y* spent on the environment, in order to make it more likely that the outcome of an environmental audit will be a favorable one. But the agent can also make the occurrence of an audit more or less probable by adjusting the effort *x* spent on standard business duties. If 2A > P, optimal audits occur when π is low, and they are conceived as a *punishment* since they bring the agent's expected wage down; in this case the agent has an incentive to make environmental audits less frequent and he can do so by increasing *x* as well. If 2A < P and the agent is not too risk averse, environmental audits are triggered instead by high financial assessments π, and they constitute a *reward* for the agent since they yield a higher expected wage; in this case the agent would like to be audited and could make audits more frequent by increasing his effort *x*.

4. CONCLUDING REMARKS AND IMPLICATIONS FOR PUBLIC POLICY

> The International Chamber of Commerce believes that effective protection of the environment is best achieved by an appropriate combination of legislation/regulation and of policies and programs established voluntarily by industry. (...) Environmental auditing is an important component of such voluntary policies. [20, p. xvii-1]

The practice of environmental auditing is currently being standardized and is spreading to many industries which, unlike the chemical industry, did not previously use such a tool for managing environmental resources. As many researchers, consultants and business people have remarked, however, environmental auditing will make a significant impact only if it is embedded within a mainstream management system and its current rewards and financial incentives.[15] Actually, this may not be the case: surveys of management practice [25, 32] suggest that companies do not explicitly link environmental audit results to the evaluation and compensation of employees. One goal of this paper was to examine whether this is nevertheless possible and desirable. The analysis concedes that protecting the environment is generally not the main objective of the firm, but the principal may consent to do so because environmental negligence can have significant consequences on profit. The agent is therefore expected to first take care of traditional business functions but to devote a "reasonable" fraction of his time to environmental protection. The agent's compensation is linked to his performance in standard business tasks, which is routinely monitored, and to the assessment of his environmental diligence whenever it is audited.

On the normative side, the first two propositions prescribe that, in a context where employees have some discretion on how they will distribute their effort between standard business duties and

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[15] See, for instance, ICC [20]: "To be effective, [audit] reviews need to be conducted within a structured management system, integrated with overall management activity."

environmental protection, the occurrence of environmental audits and the optimal wage structure should depend on the importance of the employees' prudence (or precautionary motives) relative to their risk aversion. When prudence dominates risk aversion, environmental audits should be triggered by high financial assessments, and the wage of an audited agent should go up on average. When it is risk aversion that dominates, however, environmental audits should be held if standard business assessments are low, and the expected compensation of an audited employee should be lower than the wage when no audit occurs.

On the positive side, these results predict therefore that environmental audits will happen more frequently when the employees' attitude towards risk is strongly driven by precautionary motives, because in this case such audits constitute a "reward" rather than a punishment.

The present study also yields implications for the analysis and focus of environmental public policy. First, it deals with some ramifications of what can be seen as a rather recent public policy instrument, namely active support of standards for internal and external environmental audits,[16] that *pierces the corporate veil* and explicitly addresses management processes. This departs from the usual economic approach to environmental regulation, which rather considers instruments such as command and control regulations, effluent fees and marketable permits, that are conceived as external constraints on the firm seen as a "black box". Most environmental resources are allocated

[16] Exploring the reasons why standards for voluntary environmental audits have become another tool of environmental public policy is beyond the scope of this paper. Let us simply argue informally that, as for the adoption of technological standards, public support to specific rules for environmental auditing might be necessary because of the public-good nature of management processes, and also because of the delays and difficulties of markets to coordinate and converge over common norms. Agreeing rapidly on standards for environmental auditing may yield various benefits. First, failure to achieve this can be detrimental to trade and competition. Furthermore, harmonization of environmental auditing might have a significant impact on contracting habits: it could make the results of environmental audits verifiable by third parties and in particular the courts, so contingent contracts based on those results would become feasible. This paper bears strongly on the latter.

by managers within business firms.[17] *Organizational failure* could therefore be as important a cause of environmental depletion as market failure. This study represents an additional step indicating how a full-fledged examination of environmental regulation could pay more attention to policy instruments such as environmental auditing standards, which directly impact on the way managers operate within the firm.[18]

Our analysis might also contribute to a rather active debate nowadays, as to whether environmental public policy can make firms more profitable or would rather increase their cost and harm their relative market position [28, 29]. Proposition 2 suggests that a *voluntary* approach to environmental regulation, that contributes here to harmonize practices of environmental auditing and therefore lower its cost,[19] might actually implement the former scenario. Indeed, in the above model the principal is free to never audit the agent's degree of environmental care (that is, to set $m(\pi) \equiv 0$). This would surely happen when the cost of environmental auditing is prohibitive; and in this case, given that the principal can commit to such a no-audit policy, incentive compensation and the firm's profits would correspond to those of a situation where environmental audits are absent from the firm's choice set. If the cost of environmental auditing decreases sufficiently, however, environmental audits might occur (i.e. $m(\pi) > 0$ at some realizations of π). When this happens, the firm's *ex ante* profits must be greater than in a situation where no such audits are possible, for it

[17] According to some recent studies by the United Nations [21], for instance, the world's 500 largest companies are responsible for 70% of world trade, 60% of foreign investment and 30% of world gross domestic product.

[18] Other such instruments might include corporate law, court-imposed organizational remedies, product eco-labelling policies, and employee criminal liability.

[19] As one indication of the benefits harmonization may bring, according to [30] Ciba Clayton took three man-years to establish the eco-management system at its first registered site in the United Kingdom, including time talking with other companies regarding the requirements of the then-nascent standards. The company estimates that the time would be cut by two-thirds under the final version of EMAS.

would otherwise have preferred the no-audit policy! Proposition 3 could provide a rationale for this. It shows that a positive probability of environmental audits can make effort expended on standard business activities complementary to that spent on protecting the environment; that is, if the agent cares more about the environment, then he would benefit from also working harder on standard business tasks. This suggests that overall incentive costs might decrease significantly with the availability of cheaper and contractible environmental audits.

APPENDIX: PROOFS OF THE PROPOSITIONS

Proof of proposition 1. Statement (i) comes directly from the assumptions, in particular assumption 4, and equations (5) and (6).

To show statement (ii), consider (7) and note that, since $\sum_\epsilon h_y(\epsilon * y) = 0$ and h_y/h is nondecreasing in ϵ, it must be the case that $h_y(\epsilon * y) \leq 0$ when ϵ is small and $h_y(\epsilon * y) \geq 0$ when ϵ is large. The result now comes from the fact that $1/U'(\cdot)$ is an increasing function.

To prove (iii), first take the expectation with respect to ϵ on both sides of equation (7). This gives

$$\forall \pi \quad \frac{1}{U'(s(\pi))} - \sum_\epsilon h(\epsilon|y) \frac{1}{U'(w(\pi,\epsilon))} = 0 \, . \qquad \textbf{(A.1)}$$

If $-2(U''/U') \leq -U'''/U''$, then $1/U'$ is a concave function. By Jensen's inequality we have that

$$\forall \pi \quad \frac{1}{U'(s(\pi))} - \frac{1}{U'\left(\sum_\epsilon w(\pi,\epsilon) h(\epsilon|y)\right)} \leq 0 \, . \qquad \textbf{(A.2)}$$

Hence $\forall\pi$: $\sum_\epsilon w(\pi,\epsilon)h(\epsilon|y) \geq s(\pi)$. If $-2(U''/U') \geq -U'''/U''$, on the other hand, the function $1/U'$ is convex. Applying Jensen's inequality to (A.1) once again, one gets an expression identical to (A.2) but with a reversed inequality. Therefore, $\forall\pi$: $\sum_\epsilon w(\pi,\epsilon)h(\epsilon|y) \leq s(\pi)$. *Q.E.D.*

Proof of proposition 2. The first-order necessary conditions for $m(\cdot)$ - the probability of making an environmental audit - in problem (2) are given by

$$(s - K - \sum h w) + \left(\sum U'(w)h - U'(s)\right)\left(\delta + \gamma \frac{f_x}{f}\right) + \lambda \sum U'(w) h_y \;\begin{matrix} \geq 0 \\ = 0 \text{ if } 0 \\ \leq 0 \end{matrix} \tag{A.3}$$

Using equations (5) and (6), the left-hand expression simplifies into

$$s - \frac{U(s)}{U'(s)} + \sum\left[-w + \frac{U(w)}{U'(w)}\right]h - K. \tag{A.4}$$

Taking the derivative with respect to π, we get

$$\frac{UU''s_\pi}{(U')^2} + \sum_\epsilon\left[-\frac{UU''w_\pi}{(U')^2}\right]h. \tag{A.5}$$

This reduces to

$$-\frac{U''(s)s_\pi}{(U'(s))^2}\left[-U'(s) + \sum_\epsilon U'(w)h(\epsilon|y)\right] \tag{A.6}$$

by using equation (7) and taking its derivative with respect to π. By the assumptions and proposition

1 (i), the sign of the latter expression depends on the sign of the term within brackets.

Clearly, $\sum_\epsilon U(w(\pi,\epsilon))h(\epsilon|y) - U(s(\pi)) \leq U(\sum_\epsilon w(\pi,\epsilon)h(\epsilon|y)) - U(s(\pi))$, by the concavity of U and Jensen's inequality. Now, if $2A \geq P$, proposition 1 (iii) implies that the latter expression is nonpositive. This entails that (A.6) is also nonpositive, and consequently the left-hand expression of (A.3) is nonincreasing in π. Hence, if $m(\pi)$ is positive, this will certainly happen at low values of π. This proves statement (i).

To prove (ii), note that the braketed term in (A.6) can be written as:

$$\sum_\epsilon U(s(\pi)+k(\pi,\epsilon))h(\epsilon|y) - U(s(\pi)) . \tag{A.7}$$

By proposition 1 (iii), $\Sigma_\epsilon k(\pi,\epsilon)h(\epsilon|y) > 0$. Thus (A.7) will be nonnegative, for all π, if the agent's risk aversion is sufficiently low. In this case, the left-hand expression in (A.3) will be nondecreasing. So if $m(\pi)$ turns up positive, it will do so at large values of π. *Q.E.D.*

Remark. The conditions of the proposition can be made sharper if, for example, the agent's utility function exhibits constant *relative* risk aversion. In this case, let $U(z) = (\alpha/(1-\alpha))(z/\alpha)^{1-\alpha}$ where α is the coefficient of *relative* risk aversion. Following the proof of proposition 2, the comparison between the two terms within brackets in (A.6), $U(s)$ and $\sum_\epsilon U(w)h$, is now between

$$\left(\frac{s}{\alpha}\right) \quad and \quad \left[\sum_\epsilon \left(\frac{w}{\alpha}\right)^{1-\alpha} h\right]^{\frac{1}{1-\alpha}} . \tag{A.8}$$

By (7) we have that:

$$\frac{1}{(s/\alpha)^{\alpha}} = \sum_{\epsilon} h \frac{1}{(w/\alpha)^{\alpha}} \quad ,$$

$$so\left(\frac{s}{\alpha}\right) = \left[\sum_{\epsilon} h \left(\frac{w}{\alpha}\right)^{\alpha}\right]^{\frac{1}{\alpha}} \quad . \tag{A.9}$$

Thus, s/α is larger than the right-hand term of (A.8), and so $m(\pi) > 0$ at low values of π, if $\alpha < 1/2$. When $\alpha > 1/2$, on the other hand, s/α becomes smaller than the right-hand expression in (A.8), so $m(\pi)$ is positive at high values of π.

Proof of proposition 3. Consider the incentive compatibility constraint of problem (1), and denote as *EU* the objective - the expected utility - which the agent seeks to maximize. Let us compute the following cross partial derivatives:

$$\forall \pi \quad \frac{\partial EU}{\partial x \partial m(\pi)} = \sum_{\epsilon} [U(w(\pi,\epsilon)) h(\epsilon|y) - U(s(\pi))] f_x(\pi|x) \quad . \tag{A.10}$$

$$\forall \pi \quad \frac{\partial EU}{\partial y \partial m(\pi)} = \sum_{\epsilon} U(w(\pi,\epsilon)) h_y(\epsilon|y) f(\pi|x) \quad . \tag{A.11}$$

Notice that the right-hand side of the latter equation is always positive because of the monotone likelihood property of *h*. By theorem 5 in [26], it follows that the agent's optimal environmental effort *y* will increase whenever $m(\pi)$ increases. Notice also that, by the results of the previous subsections, the right-hand side of (A.8) is nonnegative under the circumstances described in proposition 3. Again, we conclude that the agent's optimal effort on standard tasks would increase after an increase of $m(\pi)$ in the relevant range. This proves the proposition. *Q.E.D.*

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