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Environmental Performance Indicators and Executive-Employee Risk Sharing

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Abstract

A principal-agent approach is used to address issues of environmental risk sharing within a firm. The principal (top management), fearing penalties for environmental damages, wants to avoid environmental harm and induce the agent (employee manipulating hazardous materials) to take appropriate actions to achieve due diligence.
Penalties for environmental violators are increasingly severe; EPA fines for environmental offences amounted to $767 million in 1996 (Friedman 1997). It is now crucial that firms take actions to prevent environmental hazards in order to demonstrate due diligence\(^1\) in a court of law. This places a definite burden on officers and directors (O&D) to effectively control the firm’s activities in order to meet due diligence criteria and avoid liability for environmental offences (Ibbotson and Phyper 1996). The obligation to meet such criteria is a strong motivating force for a firm to adopt an environmental management system (EMS).

A firm that adopts an EMS to establish due diligence engages in an agency relationship. In this relationship the principal, fearing financial penalties for environmental damages, wants to induce the agent (employee in direct contact with the potential environmental hazard) to take preventive actions, avoid environmental harm, and achieve due diligence. The difficulty arises from the principal's inability to observe perfectly the actions of the agent due to high monitoring costs and technical unfeasibility. The principal can only observe output (environmental stewardship) to infer the agent's level of compliance effort. The principal's problem is to design an incentive program that will induce the agent to take the best action from the viewpoint of the principal, reducing to a minimum the agent's incentive to shirk.

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\(^{1}\) Due diligence can be demonstrated when "systematic efforts to prevent, detect and correct violations" are clearly and thoroughly disclosed, according to the United States EPA (1998).
Another difficulty specific to environmental management is the uncertainty surrounding environmental performance indicators and the corresponding problems it causes to the efficient P-A contract. This is the focus of the present paper.

**Statement of the Problem**

The firm's top management (principal) wants to make sure her employee (agent) is acting responsibly vis-à-vis the environment. If an environmental incident were to occur, it could result in a significant fine (Friedman 1997; Ibbotson and Phyper 1996), the loss of the firm's reputation, a possible decrease in stock valuations (Laplante and Lanoie 1994), and even individual liability or culpability (Friedman 1997; Ibbotson and Phyper 1996; Metcalf et al 1996). The principal uses a compensation payment scheme $y(\cdot)$ to optimize the agent's compliance effort ($e$), in order for his behavior to be aligned with the firm's environmental policy. Only with a properly designed scheme can the principal elicit appropriate levels of environmental stewardship and thus, meet the due diligence test.

The principal has a utility function, $U_P(\cdot)$, and risk neutrality is assumed on her behalf, that is, $U_P''(\cdot) = 0$. The agent has a utility function, $U_A(\cdot)$, which is twice continuously differentiable, strictly increasing and concave to represent risk aversion (i.e., $U_A'(\cdot) > 0$ and $U_A''(\cdot) \leq 0$). His utility is separable in income and effort. The agent prefers less effort to more effort, therefore the cost of effort to the agent, $C(e)$, is positive and increasing (i.e. $C'(e) > 0$ and $C''(e) > 0$) and is denominated in terms of utils.

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2 An active production process is assumed. One could imagine stewardship being achieved through halting production, but it is reasonable to assume firms will choose to abate using other means.
Using EPI

The Model

In a previous paper (Goldmith and Basak 1999), a model was developed to describe the relationship between a principal and her agent in an environmentally risky firm. In that model, it was assumed that the principal could infer the level of the agent's compliance effort by observing output (i.e. stewardship) and that she could motivate her agent to deliver stewardship by paying a compensation payment ($y(\cdot)$). This payment was a function of a stewardship output measure ($x$), which was naively free of uncertainty. In reality, this true stewardship measure unfortunately does not exist.

Extending the P-A concept from that previous paper, the agent continues to receive his payment, but the compensation payment ($y$) now depends on an environmental performance indicator (EPI) score denoted by $\theta$. EPI are a series of metrics used to measure compliance in either the day-to-day activity of the firm or for annual environmental impact assessments. These "gauges" are being used more and more by proactive companies (Metcalf et al 1996; Epstein 1996) as they give an indication of the company's environmental impact and help managers implement actions to improve environmental compliance. An example of such an EPI is Nortel's environmental performance index. Their index is an aggregate score based on environmental releases, number of fines received, etc. and is similar to that of other industry efforts\(^4\) to develop environmental performance metrics.

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\(^3\) U\(_A\) being separable in effort rules out income effects on the choice of effort (Rollins and Briggs 1996).

\(^4\) Other firms such as Niagara Mohawk Power, Chevron, Browning-Ferris Industries (see Epstein 1996) have
Now, consider the following model, which highlights the contractual components that affect the attainment of the principal’s objective, namely stewardship:

Optimand

\[
\max \int U_p (\theta - y(\theta) - K_\theta) f(\theta, e) \, d\theta \\
y(\theta), e
\]

(1)

Participation constraint

\[
\int U_A (y(\theta)) f(\theta, e) \, d\theta - C(e) \geq U_{0A}
\]

(2)

First order incentive compatibility constraint\(^5\)

\[
\int U_A (y(\theta)) f_c(\theta, e) \, d\theta = C'(e)
\]

(3)

The resulting optimal risk-sharing rule is

\[
\frac{U_p' (\theta - y(\theta) - K_\theta) = \lambda + \mu [f_c(\theta, e) / f(\theta, e)]}{U_p' (y(\theta))}
\]

(4)

The EPI score (\(\theta\)) affects the principal's utility \(U_p (\theta - y(\theta) - K_\theta)\) in three ways. First, as \(\theta\) increases, it directly increases her utility, as she prefers better environmental performance (as measured by the EPI score) to worse performance. Secondly, increases in \(\theta\) lead to higher payments to the agent \((y(\theta))\), which are costly to the principal, decreasing her utility. Lastly, the transaction costs associated to the EPI \((K_\theta)\), which include the cost of designing the EPI and the collection and entry of data in the information system, give disutility to the principal.

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\(^5\) For the first order approach to be valid, it must be assumed that the agent's expected utility is concave in effort (Jewitt 1988).
The ratio of the marginal utilities \( \left( \frac{U'_P}{U'_A} \right) \) in (4) shows that incremental changes in the payment \( (y) \) affect both the principal and the agent. The principal’s utility \( (U_p) \) increases with a marginal increase in the agent's optimal level of effort \( (e) \), as more effort leads to higher stewardship (shown by \( f_e(e) \)). The agent's utility increases indirectly because effort leads to higher EPI scores (again, shown by \( f_e(e) \)) and consequently increases the agent's payment \( (y(0)) \).

\( \lambda \), in (4), is the basic marginal utility wage paid by the principal to the agent, or the principal’s shadow price for the participation constraint (Equation 2). It can be interpreted as a fixed wage the principal needs to pay when she can directly observe the agent’s effort. The relative effort multiplier, \( \mu \), is the principal's shadow price for the first order constraint (Equation 3). \( \mu [\cdot] \) shows how costly (in terms of the principal’s utils) it is to cause the agent to produce the optimal compliance effort\(^6\).

The likelihood ratio in (4), \( f_e(\theta, e) / f(\theta, e) \), was derived by rearranging the Kunh-Tucker condition (differentiated with respect to \( y \)) of the maximization problem; maximizing (1) subject to (2) and (3). This ratio is assumed to be monotone, non-decreasing, and concave in \( \theta \). This ratio is a significant component of the P-A model as it illustrates the strength of relationship between effort and the EPI score. It measures the ratio of the likelihood of observing a given EPI score \( (\theta_i) \) as the agent chooses the optimal effort level

\(^6\) Rollins and Briggs (1996) give a similar interpretation of \( \mu [\cdot] \) in the context of wildlife damage.
(e*) to the likelihood of observing this same θ, as the agent chooses any level of effort (e) (Varian 1992). Therefore, the higher the ratio, the more likely the principal will be paying for high levels of effort. As the likelihood ratio increases, it is possible for the principal to infer that the agent is giving a high level of effort (e*) and not a sub-optimal level of effort (ei), thus reducing the probability of overly low EPI scores.

Since compliance effort (e) is thought to be driving θ, then, the higher the likelihood ratio, the more output (the EPI score) is a function of effort. So the principal pays μ[-] when the relationship between e and θ is thought to be strong. This means that the principal pays the agent a fixed amount (λ) plus an additional "motivational" amount (μ[-]) which stems from the first order constraint (Equation 3) (Goldsmith and Basak 1999). μ[-] renders the agent’s compensation (y(-)) dependent on the environmental performance measure (θ) and effort (e) via this likelihood ratio f(θ)/f(e)⁷.

It is important to note that, in the limit, if suboptimal effort (e) has no effect on observing a given EPI score, then the denominator of the likelihood ratio (f(·)) is zero, thus the ratio is indeterminate. More realistically, if suboptimal effort levels have little effect on obtaining a given EPI score, then the denominator approaches zero and the likelihood ratio can take the maximum value of ∞. Thus, if e* leads to a high probability of observing θ, the principal will pay a high premium to the agent. In other words, as effort is

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⁷ Hueth and Ligon (1998) give a similar interpretation of the likelihood ratio in the context of the produce industry.
increasingly significant in terms of observing $\theta_i$, the agent is delivering a differentiating type of effort ($e^*$), a motivational wage is justified, and compensation rises above the fixed wage ($\lambda$). This implies that increased payments to the agents are justified as the principal, by means of the payment scheme, has a greater ability to control the outcome (the EPI score). Conversely, for example, when the EPI score $\theta_i$ is function of an act of God (i.e. $P(\theta_i| e^* = P(\theta_i| e_i)$) rather than the agent’s effort, the optimal payment scheme reverts to $\lambda$.

If it is imperative for the principal to elicit high effort and she only has $\theta$ on which to base compensation, the question is then: how difficult is it to obtain this stewardship measure ($\theta$)? If this measure is readily available and reliable, the efficient contract can be drawn up and stewardship will result. If it is difficult, the contract breaks down.

**EPI and Uncertainty**

The state of the firm’s stewardship is a difficult measure to obtain due to the complexity of environmental performance assessment. There are five types of measurement difficulties associated with EPI. These give rise to managerial uncertainties, which in turn affect the formulation of an efficient P-A contract:

First, pollution is a *dynamic problem*. Products, production processes and their associated pollutants change continuously and this requires metrics that can adapt to these changes. Also, there are the cumulative effects of pollutants that may only be observed over long periods of time. Trace amounts barely observable today may build up, causing significant
environmental damage over the long run. Secondly, hidden hazards are involved. The lack of observability for some pollutants, either due to improper auditing, or to technological limitations of pollution measurement tools, can make EPI less reliable measures of true stewardship. Thirdly, the subjectivity of the EPI score is problematic. Choices as to which pollutant or waste is to be tracked are influenced by various factors such as the cost of sampling (i.e. cheaper and less precise sampling procedures may be chosen), current legal requirements, the environmental staff’s current knowledge and public expectations. There has been much public debate in recent years as to which emission measures should be included in an overall EPI index (e.g. the case of City of Columbus\textsuperscript{8}). Fourthly, there is a problem of data aggregation. An EPI score consists of a series of imperfect measures of the firm’s level of compliance, such as: air emissions (e.g. tons of $\text{NO}_{x}$, $\text{SO}_{x}$), effluents (e.g. BOD readings), spills, etc. These environmental statistics are aggregated into a single index or score and therefore may not give a clear or direct indication of the mapping between effort and stewardship. Finally, there is a significant problem of stochastic environmental events. Pollution output may be stochastic in nature and not fully the result of direct or preventive management strategies. Many factors outside the workers’ control influence environmental performance, such as the environment's buffering capacity, weather, cumulative effects or acts of God. Hence, if $\theta$ is high, top management cannot be entirely certain whether it is due to the agent’s effort or to luck.

Limitations {1-4} result in performance measures that are unclear and cumbersome to define, while the fifth limitation, stochastic processes, contributes an added level of managerial uncertainty. For example, one

\textsuperscript{8} This study was an outcome of the “unfunded mandate” debate in the US during the late 1980’s and early 1990’s. The question arose as the Federal government required municipalities to test for a specified list of water pollutants in their drinking water (Priorities ’95 Technical Advisory Committee 1995).
might believe that the Exxon Valdez disaster was the result of mismanagement on the part of the corporation. Does this mean that if the disaster had not occurred on that fateful day in March Exxon’s true performance was any different? What is being measured when using EPI and how well are these EPI mapped to true environmental stewardship? The output produced by the agent (measured by the EPI score) is uncertain, possibly making for an imprecise and unclear measure of true stewardship.
Whereas in most firms, performance indicators are well established for profit-center activities, allowing for proper mapping between incentives and effort, the above characteristics make EPI implementation difficult. For example, a cost reduction goal is very clear to a production manager. He knows where savings can be realized, through downsizing, seeking less expensive suppliers, etc. The outcome of the cost reduction mandate is measurable in dollars and therefore easily recognizable. Monetized measures of performance are a prevalent part of corporate culture and are clear for both internal and external stakeholders. But for the environmental manager, a stewardship improvement goal is quite a nebulous concept, as its measurability is based on a non-monetized EPI score. Therefore, a manager or employee who performs a series of tasks to improve environmental quality may not see the results as directly as those efforts directed towards profit-centered or cost-reducing activities.

**Implications**

**Implications for the Agent**

For the agent, the lack of precision and clarity associated with the EPI creates an incompatibility between his incentives and his corresponding participation; his delivery of an appropriate level of effort and the corresponding true stewardship output. If the agent's incentive payment is based on an imprecise measure, he may chose not to participate as the risk of being unfairly evaluated may be too high (i.e. the participation constraint will bind). The lack of precision may also fall short of providing the agent an incentive to select a high effort level, as opposed to a low effort level (i.e. the first order constraint may not bind). This would certainly defeat the principal’s goal of eliciting maximum effort from the agent, in order to share and reduce the firm’s risk, and ultimately attaining true stewardship.
Implications for the Principal

One purpose of EPI metrics is to enable benchmarking and measure progress related to agent performance. With poor information on environmental performance, the firm's policy will be poorly implemented and tracking its progress will be difficult. Precision assures the principal that she is paying her employees for results. Remember that the principal is paying the agent based on stewardship output; if the stewardship measure is poorly specified, she has no way of measuring her workers' performance or progress. Also, an imprecise EPI may cause the principal to offer the wrong incentive for the agent, resulting in sub-optimal levels of effort, which in turn will negatively affect stewardship.

For example, take a firm that has an EPI that gives importance (subjective) to a given pollutant (e.g. 10% in the overall EPI score is allocated to water pollutant z) but has poor measurement for that pollutant (e.g. its gauge only traces effluents in PPM instead of PPB). Under detecting this "important" pollutant may give the firm a false sense of stewardship and an overly high EPI score. This in turn will increase the payment to the agent, giving him a signal that he is doing his job correctly. While in the short run this may be appropriate, in the long run, true stewardship may not have been attained.

Lastly, an advantage of precise metrics for performance measurement is the reduction of uncertainty in terms of the firm’s liability. If the firm's stewardship state is unknown, the liability problem of hidden hazards may prove not only distracting for the principal but may lead to poor decision making.
**Industry Response**

The lack of precise EPI is a problem of major concern for environmentally risky firms. New initiatives by the International Organization for Standardization are an indication of the need for standardization in firm environmental performance evaluations (EPE). Their efforts involve the establishment of an international standard, namely ISO 14031, that would permit corporations worldwide to be compared through the use of standardized EPE and a corresponding set of EPI (Cornish 1997). Once an agreement is reached on ISO 14031 and standardized EPI, it will facilitate firms’ efforts to measure their environmental performance, enabling to reduce the burden of the current ad hoc EPI creation. Standardized EPE and EPI will give guidance and institutional support to firms striving for stewardship and may help reduce the uncertainty associated with these metrics.

**Conclusion**

The model shows that the use of EPI-based compensation will have imperfect results in terms of incentive alignment, as environmental stewardship is difficult to quantify. If uncertainty is pervasive, in terms of measuring output (i.e. EPI are flawed), then it may be difficult to share the environmental risk and deliver the appropriate level of stewardship. The complex nature of environmental problems and the firm’s inability to measure true stewardship will continue to make it difficult to implement contracts based on the traditional principal-agent approach where incentive payments are aligned with output. Either of two strategies must occur to more closely achieve the efficient P-A contract where risk is shared; 1) improved metrics and 2) alternative risk-sharing mechanisms.
With respect to improving the metrics, additional work like that which is currently occurring in the industry is needed to address the above measurement problems. With such a highly charged issue for the firm, precision and consistency are paramount for reducing dissonance between the principal and the agent.

In terms of alternatives, it also may be the case that simple incentive-based contracts, based on performance are insufficient to achieve the firm’s true strategy, and alternative mechanisms are needed. In a previous paper (Goldsmith and Basak 1999), a paper trail signal, commitment premiums and merit deductibles were offered as additional mechanisms for achieving an efficient labor contract, promoting greater risk sharing and improved stewardship.
REFERENCES


