

Environmental Management Systems and Executive- Employee Risk Sharing

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Abstract. A principal-agent (P-A) model is used to analyse the effect of environmental performance indicators (EPI) on environmental risk sharing within the firm. To achieve due diligence, the principal (top management), having to use imperfect performance indicators and fearing penalties for environmental damages, wants to avoid environmental harm and induce the agent (employee manipulating hazardous materials) to take appropriate action. To motivate the agent, the principal offers an incentive contract based on environmental stewardship performance (as measured by EPI). Environmental stewardship being difficult to measure, due to high levels of uncertainty surrounding EPI, creates impediments to the establishment of an efficient P-A contract.

Key words: principal-agent, environmental performance indicators, output uncertainty, environmental risk, compliance, incentives

This paper has not been submitted elsewhere in identical or similar form, nor will it be during the first three months after its submission to the Publisher

1. Introduction

A firm that adopts an environmental management system (EMS) engages in an agency relationship. In this relationship the principal, fearing financial penalties for environmental damages¹ and wanting to achieve due diligence², tries to induce the agent (employee in direct contact with the potential environmental hazard) to take preventive actions and avoid environmental harm. The difficulty arises from the principal's inability to perfectly observe 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 and reduce to a minimum the agent's incentive to shirk (Varian 1992). This is the moral hazard problem that characterises many relationships, such as: insurance company–policyholder or landlord–tenant. In addition to the hidden action/moral hazard problem, environmental management is subject to an additional form of information asymmetry. While many proprietary organisations have clear and measurable optimands such as profit maximisation, environmental stewardship³ is difficult to measure due to high levels of uncertainty surrounding environmental performance indicators (EPI). This paper explores the impact of this uncertainty on the establishment of the efficient principal-agent (P-A) contract.

2. Statement of the Problem

To ensure her employee (agent) is acting responsibly vis-à-vis the environment, the firm's top management (principal) uses a compensation payment scheme, $y(\cdot)$, to optimise the agent's compliance effort (e), so that his behaviour is in line with the firm's environmental policy. Only with a properly designed scheme can the principal elicit appropriate levels of environmental stewardship⁴ and meet the due diligence test.

The principal has a utility function, $U_P(\cdot)$, and risk neutrality is assumed on her behalf, (i.e., $U_P''(\cdot) = 0$). 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 effort⁵. 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.

3. Using EPI

The Model

In a previous paper (Goldsmith 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. Unfortunately this true stewardship measure does not exist in the real world.

Extending the P-A concept from that previous paper, the agent continues to receive his payment, but the compensation payment ($y(\cdot)$) now depends on an environmental performance indicator (EPI) score denoted by z . 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 (Epstein 1996; Metcalf et al. 1996) because they provide 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 Networks' environmental performance index⁶. Nortel's index is an aggregate

score based on environmental releases, number of fines received, etc., and resembles other industry efforts⁷ to develop environmental performance metrics.

The following model highlights the contractual components that affect the attainment of the principal's objective, namely stewardship:

Optimand

$$\text{Max}_{y(2), e} \int U_p (2 - y(2) - K_\theta) f(2, e) d2 \quad (1)$$

Participation constraint

$$\int U_A (y(2)) f(2, e) d2 - C(e) \geq U_{0A} \quad (2)$$

First order incentive compatibility constraint⁸

$$\int U_A (y(2)) f_e(2, e) d2 = C'(e) \quad (3)$$

The principal wishes to maximise her utility ($U_p(\cdot)$), subject to the agent's willingness to participate (participation constraint (2)) and to the alignment of his incentives with his effort level (incentive compatibility constraint (3)). The participation constraint (2) is included in the contract in order to offer the agent at least as much utility as his next best opportunity (his reservation utility, U_{0A}). The incentive compatibility constraint (3) is introduced in the model to ensure that the agent does not deliver a low level of stewardship and that the high effort alternative is always preferred⁹.

Solving the principal's problem with respect to the payment scheme (y), the resulting optimal risk-sharing rule is:

$$\frac{U_P'(\theta - y(\theta) - K_\theta)}{U_A'(y(\theta))} = \lambda + \mu [f_e(\theta, e) / f(\theta, e)] \quad (4)$$

The EPI score (2) affects the principal's utility $U_P(2 - y(2) - K_\theta)$ in three ways. First, as 2 increases, it directly increases her utility because she prefers better environmental performance (as measured by the EPI score) to worse performance. Second, increases in 2 lead to higher payments to the agent ($y(2)$). These are costly to the principal thereby decreasing her utility. Lastly, the transaction costs associated with the EPI (K_θ), which include the cost of designing the EPI and the collection and entry of data in the information system, give disutility to the principal.

The ratio of the marginal utilities ($U'_P(\cdot) / U'_A(\cdot)$) 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^*) because more effort leads to higher stewardship (shown by $f_e(\cdot)$). The agent's utility increases indirectly because effort leads to higher EPI scores (again, shown by $f_e(\cdot)$) and consequently increases the agent's payment ($y(2)$).

In (4), λ is the basic marginal utility wage paid by the principal to the agent; the principal's shadow price for the participation constraint (Equation 2). It can be interpreted as a fixed wage the principal must pay when she can directly observe the agent's effort. In a full information context, there would be no need to use the incentive payment $y(\cdot)$ to control compliance effort indirectly; the optimal contract would therefore be a constant wage (Kreps

1990). The principal, in that case, could directly observe the agent's level of effort and control it via the contract (Gravelle and Rees 1992).

The relative effort multiplier, λ , shows how costly it is (in terms of the principal's utils) to cause the agent to deliver the optimal compliance effort¹⁰. It is the principal's shadow price for the first order incentive compatibility constraint (Equation 3).

The likelihood ratio in (4), $f_e(2, e) / f(2, e)$, was derived by rearranging the Kuhn-Tucker condition (differentiated with respect to y) of the maximisation problem; maximising (1) subject to (2) and (3). This ratio is assumed to be monotone, non-decreasing and concave in 2 . It is also a significant component of the P-A model because 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 (2_i) as the agent chooses the optimal effort level (e^*), to the likelihood of observing this same 2_i as the agent chooses any level of effort (e_i) (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, the principal can infer that the agent is giving a high level of effort (e^*) and not a sub-optimal level of effort (e_i), thus reducing the probability of overly low EPI scores.

Since compliance effort (e) is thought to be driving 2 , the higher the likelihood ratio, the more output (the EPI score) is a function of effort. So the principal pays λ when the relationship between e and 2 appears to be strong. This means that the principal pays the agent a fixed amount (β) plus an additional "motivational" amount (λ) that stems from the incentive compatibility constraint (Equation 3) (Goldsmith and Basak 1999). The motivational amount

(:[:]) renders the agent's compensation ($y(\cdot)$) dependent on the environmental performance measure (2) and effort (e) via this likelihood ratio $f_e(\cdot)/f(\cdot)$ ¹¹ .

It is important to note that, in the limit, if suboptimal effort (e_i) has no effect on observing a given EPI score, the denominator of the likelihood ratio ($f(\cdot)$) is zero, rendering the ratio 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 4. Thus, if e^* leads to a high probability of observing 2_i , the principal will pay a high premium to the agent. In other words, as effort becomes increasingly significant in terms of observing 2_i , the agent delivers a differentiating type of effort (e^*), a motivational wage is justified and compensation rises above the fixed wage (8). This implies that increased payments to the agent are justified. The principal, by means of the payment scheme, has a greater ability to control the outcome (the EPI score). Conversely, if for example, the EPI score, 2_i , is a function of an act of God (i.e., $P(2_i)* e^* . P(2_i)* e_i$) rather than the agent's effort, the optimal payment scheme reverts to 8.

Effort

Through the compensation plan, the principal attempts to control the level of effort exerted by the agent. Critical to realising an optimum plan is understanding the marginal impacts of changes in the agent's effort. By taking the partial derivative of the maximisation problem (i.e. max (1) s.t. (2) and (3)) with respect to effort (e) the following is obtained:

$$\int U_P (2-y(2)) f_e(2*e^*) d2 = 8 \left[\int U_A (y(2)) f_e(2*e^*) d2 - C'(e^*) \right]$$

(5)

The left-hand side of the equation is the marginal expected value product to the principal of the agent's effort. Included are the marginal costs to the principal due to the disutility from paying the agent $(-y'(2)(f_e(2 * e^*)))$. The marginal benefits to the principal arise from the increased compliance effort by the agent $((2)(f_e(2 * e^*)))$; which lowers the probability of damages. The right-hand side contains three elements: 1) the basic marginal utility wage (8) ; 2) the marginal cost to the agent of increased effort $(C'(e^*))$; and 3) the increased probability of greater stewardship, and consequently higher payments to the agent, $(y'(2)(f_e(2 * e^*)))$.

If it is imperative for the principal to elicit high effort and she only has 2 on which to base compensation then the question is: how difficult is it to obtain this stewardship measure (2)? If this measure is readily available and reliable, the efficient contract can be drawn up and stewardship will result. If it is a cumbersome measure, the contract will break down.

4. 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, since pollution is a dynamic problem, products, production processes and their associated pollutants change continuously, requiring metrics that can adapt to these changes (Carlson and Sholtz 1994). There are also 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. Second, hidden hazards are involved. The lack of observability for some pollutants, due either to improper auditing or to technological limitations of pollution measurement tools (Russel et al. 1986), can make EPI less reliable measures of true stewardship. Third, the subjectivity of the EPI score is problematic. Choices governing 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. For example, 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 Columbus¹²). Fourth, 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 NO_x, 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. Also, because spills vary in terms of size and toxicity (Naimon 1994), some data, such as number of spills, do not give an appropriate signal of environmental quality. Finally, there is the significant problem of stochastic environmental events. Pollution output may be stochastic in nature (Beavis and Walker 1983; Bystrom and Bromley 1996) and not entirely 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. Therefore, if the EPI score (2) is high, senior management cannot entirely be certain whether it is due to the agent's effort or to luck.

The first four limitations result in performance measures that are unclear and cumbersome to define. The fifth limitation, stochastic processes, contributes to an additional level of

managerial uncertainty. For example, one 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 1989, Exxon's true performance was any different? What do EPI measure and how well are EPI mapped to true environmental stewardship and agent effort? The output produced by the agent (measured by the EPI score) is uncertain, possibly providing an imprecise and unclear measure of true stewardship.

Although in most firms performance indicators are well established for profit-centre 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 savings can be realised either through downsizing or alternative suppliers. The outcome of the cost reduction mandate is measurable in dollars and therefore readily recognisable. Monetised measures of performance are a prevalent part of corporate culture and are clear for both internal and external stakeholders. For the environmental manager, however, a stewardship improvement goal is a nebulous concept because its measurability is based on a non-monetised EPI score. Therefore, a manager or employee who performs a series of tasks to reduce the pollution burden may not see the results as directly as those efforts directed towards profit-centred or cost-reducing activities. As well, managers have to prioritise, in terms of importance, these monetised and non-monetised objectives.

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 choose not to participate because 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 with 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 may 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 (subjective) importance 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 seem to be appropriate, in the long run, true stewardship may not be attained.

Finally, 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 not only prove to be distracting for the principal but may also lead to poor decision making.

5. Industry Response

The lack of precise EPI is a problem of major concern for environmentally risky firms. New initiatives by the International Organisation for Standardisation are an indication of the need for standardisation in firm environmental performance evaluations (EPE). Their efforts involve the establishment of an international standard, namely ISO 14031, which would permit corporations world-wide to be compared through the use of standardised EPE and a corresponding set of EPI (Cornish 1997). Once an agreement is reached on ISO 14031 and standardised EPI, it will facilitate firms' efforts to measure their environmental performance, enabling them to reduce the burden of the current ad hoc EPI creation. Standardised EPE and EPI will give guidance and institutional support to firms striving for stewardship and may help reduce the uncertainty associated with such metrics.

6. Conclusion

The model shows that because environmental stewardship is difficult to quantify, the use of EPI-based compensation will have imperfect results in terms of incentive alignment. 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) improve stewardship metrics or 2) develop alternative risk-sharing mechanisms.

With respect to improving the metrics, additional work similar to that which is currently being done in the industry is needed to address the above measurement problems. Such a highly charged issue for the firm necessitates precision and consistency in order to reduce dissonance between the principal and the agent.

It may be that incentive-based contracts dependent on environmental performance are insufficient to achieve the firm's true strategy. An efficient P-A contract that maximises stewardship may be elusive. If true, alternative mechanisms are needed to combat this as well as other forms of information asymmetry. Mechanisms such as accountability procedures, commitment premiums and merit deductibles¹³ may prove valuable for achieving an efficient labour contract, promoting greater risk sharing and improving environmental stewardship.

Notes

¹ Penalties for environmental violators are increasingly severe; EPA fines for environmental offences amounted to \$767 million in 1996 (Friedman 1997).

² Officers & Directors need to demonstrate "due diligence" (i.e., show that they have "made systematic efforts to prevent, detect and correct violations" (United States EPA 1999). The obligation to meet such criteria is a strong motivating force for a firm to adopt an environmental management system (EMS).

³ It is important to distinguish between true stewardship and that which management decides is an appropriate risk exposure for the firm. Senior management may not choose the highest level of stewardship, but may balance the benefits and costs of their environmental strategy.

⁴ 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.

⁵ U_A , being separable in effort, rules out income effects on the choice of effort (Rollins and Briggs 1996).

⁶ Nortel Networks' Website has a more complete description of the company's environmental performance index and its environmental reporting procedure (Nortel Networks 1999).

⁷ Other firms such as Niagara Mohawk Power, Chevron, Browning-Ferris Industries (see Epstein 1996) have developed their own performance measures, either in-house or with the help of third parties.

⁸ For the first order approach to be valid, it must be assumed that the agent's expected utility is concave in effort (Jewitt 1988).

⁹ For a more complete discussion on the participation and incentive compatibility constraints, see Goldsmith and Basak (1999).

¹⁰ Rollins and Briggs (1996) give a similar interpretation of : [·] in the context of wildlife damage.

¹¹ Hueth and Ligon (1998) give a similar interpretation of the likelihood ratio in the context of the produce industry.

¹² 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).

¹³ For a discussion of these mechanisms see Goldsmith and Basak (1999).