ABSTRACT

"The Firm, its Procedures, and Win-Win Environmental Regulations"

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It has been customary for neo-classical environmental economists to assume that the link between environmental regulatory policy and the allocation of environmental resources is a perfectly rational and efficient firm which maximises profits given whatever technological, market, and regulatory constraints are imposed on it. They have rarely pierced the corporate veil to understand in microanalytic detail the management processes taking place within the firm. Yet there is a growing literature that recognises that a real firm is exceedingly complex; it may have a titular principal, but it is actually "run" by agents to whom is delegated a great deal of autonomy. Their activities are imperfectly controlled and co-ordinated by a set of interrelated management systems and a multitude of procedures for operationalising the principal's objectives.

This paper develops this view with reference to recent literature and then with an application which shows how modelling the firm's internal systems can explain an observation inexplicable in neo-classical economic terms: that strict environmental regulations might be "win-win", simultaneously reducing the firm's private costs and the external costs it imposes on the environment.

The paper starts with an explicit acknowledgement that there are organisational failures within firms. Managers have limited attention spans, information flows imperfectly between managers and employees, and employees work according to their own objectives. These organisational failures are systematic and are in many respects similar to market failures external to firms. The paper then presents a model that elaborates the role of procedures and routines in companies and shows how their existence can explain "win-win" regulations.

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> The firm in mainstream economic theory has often been described as a 'black box.' And so it is. This is very extraordinary given that most resources in a modern economic system are employed within firms, with how these resources are used dependent on administrative decisions and not directly on the operation of a market.
>
> (Coase, 1992 p.714)

> Most production in modern economies occurs within organisations, and this production is regulated only to a limited extent by prices. . . . These observations make it clear that if economists wish to understand how resources in modern economies are allocated, we must understand what goes on inside organisations.
>
> (Stiglitz, 1991 p. 15)

It has been customary among environmental economists schooled in the neo-classical tradition to assume that the link between environmental regulatory policy and the allocation of environmental resources is very simple. It is a perfectly rational and efficient black box firm, which maximises profits given whatever technological, market, and regulatory policy constraints are imposed on it. Because economists have long assumed that the firm behaves in this way, and have been content to model its behaviour as such, they saw no reason to pierce the corporate veil to understand in micro-analytic detail the management processes taking place within the firm.

This tradition has had several predictable results. One was that economists concerned with environmental problems focused their attention almost exclusively on public policy instruments applicable outside the firm. This was natural since their model provided little substance to the firm, per se. The model was more concerned with the web of market relationships between the firm and other rational economic agents, so economists naturally believed that environmental problems were caused by some market failure.

Since by assumption environmental problems had to originate in the market, it was natural to seek to solve them by fixing the market's flaws. Economists have for several generations proselytised for the cause of public policy instruments that do so. Marketable quotas which establish property rights to environmental resources, effluent taxes which increase inefficiently low prices, and legal liability for compensating victims of third-party damage are favoured instruments.[1]

A second predictable result (although not easily documented) has been that environmental damage occurred for causes that have totally escaped policy-makers' notice. Failure of organisations to co-ordinate behaviour can result in environmental accidents

[1]Regulatory failure, like market failure, has also been subject to careful academic scrutiny, albeit only relatively recently. It is because of the perceived ubiquity of regulatory failure - for example, the failure of command and control environmental policies - that there is so much interest now paid to the market-oriented policies that environmental economists have been promoting. (Cf., Crandall, 1992; Gupta, *et al*., 1993; Tietenberg, 1990.) Regulatory failure will not be a topic of this paper despite its importance.

entirely independent of failures of markets. Settings apparently free of market problems are not necessarily free of environmental risk.

A final result of the neo-classical paradigm was that although managers of business firms foundered trying to cope with the rising tide of environmental pressures, of which public policy was only one, economists had little advice to offer to them. Proffered advice came from other academics and business consultants,[2] but it lacked the rigour characteristic of economic science. In particular, there has been little rigorous analysis of how a company's environmental strategy is operationalised in the management control systems, formal and informal, that would normally convert strategy into action.

This is not a criticism of economic analysis of market failures, nor is it intended to detract from economists' well-founded enthusiasm for market-based policy instruments. Rather, the point is that the logic that looks for failed assumptions to the neo-classical model of the market should be carried into the firm. It is inconsistent, albeit convenient, to assume that markets are flawed but that firms are perfect.

Firms are, of course, exceedingly complex institutions, and profit maximisation is far from trivially easy even in a context of relatively simple and stable market relationships. No reasonably large firm is run by a sole and rational chief executive – a corporate "principal" - who maximises the firm's value. All are run by vast numbers of employees - or "agents" - to many of whom may be delegated a great deal of autonomy. Their activities are controlled and co-ordinated, however, by a set of interrelated management systems and a multitude of procedures for operationalising the principal's objectives.[3]

The point to emphasise is that the principal does not directly make the decisions that determine the firm's performance. Rather, the process is indirect. Profit maximisation must be accomplished - or attempted - via this network of necessarily imperfect systems and procedures that link the principal's objectives to the agents' actions.[4] We use the term "management systems" broadly to include formal systems (budgeting, accounting, compensation, etc.), corporate policies, standard operating procedures (SOPs), and simpler work routines and habits, many of which may not be explicitly defined.[5] These systems are the grist of consulting firms and the management literature, they hold centre stage in business school curricula, and they preoccupy practising managers. To assume that the firm simply and perfectly maximises profit is to assume away one of the main challenges facing its managers.

Thus, the link between environmental regulatory policy and the allocation of environmental resources is complex, multi-step, and imperfect. Designing regulatory policy is only a first step. That policy may occasionally intervene in the management systems themselves,[6] but more commonly, it alters the external rules to which the corporate principal is subject. These altered rules must then induce the principal to change the management systems which play a crucial role motivating and controlling the actions of the agents. Finally, the agents must respond to the changes in the management systems, presumably in consort with the objectives of both the corporate principal and the regulatory policy maker. Any environmental impact only appears at this last step.

In these steps, there are invariably slips that break the direct link traditionally assumed between the regulator and the environment. Managers have limited attention spans, information flows imperfectly between managers and employees, and employees pursue their own objectives. All these imperfections and more cause organisational failures within the

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[2] Good examples of work in this genre are Epstein (1996a,b,c).

[3] To keep the chapter focused, we will maintain the traditional assumption that the firm's principal desires to maximise profits. Our point of departure from neo-classical economics is to reject its assumption that the firm can be represented as a single perfectly rational decision-maker.

[4] For an elaboration of some of this, see Milgrom and Roberts (1992) Chapter 4.

[5] The notion of routines is developed in Nelson and Winter (1982) and Postrel and Rumelt (1992).

[6] For example, in a Canadian case over illegal sulphur emissions, a court ordered the company, Prospec, to obtain ISO 14001 certification.

firm. As we will argue in this chapter, these organisational failures are systematic, they are in many respects similar to the market failures long studied by environmental economists, and there are instruments available to fix them analogous to the instruments available to fix markets.

Because our focus is within the firm, our analysis is not just relevant to the public policy maker. It should be obvious that organisational failures are relevant to the firm's management as well, since their manifestation is frequently unachieved profit potential. To give an example on which some of the following analysis will focus, if a firm is systematically losing money by wasting environmental resources, the firm's management would like to know it as much as, and possibly more than, the environmental policy maker.

The first objective of this paper is to argue that designing corporate environmental policy should take an equal position on the economists' agenda to designing public environmental policy. In addition to studying the appropriate economic incentives confronting a firm (or its principal) in a decentralised market economy, environmental economists should also study the appropriate incentives facing the agents within the firm. The two areas of study are intimately linked, but they are not the same. We will show in this paper that behind the corporate veil lie causes of systematic organisational failure that are analogous in many respects to problems of externalities in the context of market-mediated transactions. And there are management tools to mitigate these organisational failings just as there are public policy tools (e.g., Pigovian taxes, rules of civil and criminal liability, and marketable property rights) that might remedy market failings. In the lexicon of organisational economics, the causes of organisational failure include perverse incentives, hidden actions, imperfect information, strategic behaviour, and moral hazard. The management tools include monitoring technologies, contract design, task allocation decisions, centralisation and decentralisation of authority, and accounting systems, *inter alia*.

The paradox of low hanging fruit

> Economists . . . tend to regard energy efficiency like the man whose friend draws his attention to a £20 note lying on the pavement. 'It can't be,' he says. 'If it were, somebody would have picked it up.'
>
> Every scheme to encourage investment in energy efficiency finds plenty of what the industry calls 'low hanging fruit' - projects with succulent returns. Robert Ayres, in a paper at a conference on energy and the environment in the 21st century at the Massachusetts Institute of Technology last year, drew attention to the 'energy contest' begun in 1981 by the Louisiana division of Dow Chemical, to find capital projects costing less than $200,000 with payback times of less than a year. In 1982 the contest yielded 27 projects in which Dow invested $1.7m: the return averaged 173% (a payback period of about seven months). The contest continued, with more projects backed each year. In 1988 95 projects were picked, costing a total of $21.9m - and yielding an average return of 190%.
>
> (*The Economist*, 1991 p.15)

Dow's experience is not unique. The 3M company has eliminated 500,000 tons of waste and pollutants and saved $482 million in so doing and another $650 million by energy conservation since it started its 3P ("Pollution Prevention Pays") programme in 1975. The Centre for the Exploitation of Science and Technology ran an eighteen-month project in the UK to test the benefits of waste reduction and clean technologies. The project saved more than £11 million a year for the eleven participating companies, mostly from simple changes in processes that reduced inputs of water, energy, and raw materials. The US Environmental Protection Agency has estimated that if the entire country were to switch to energy-efficient

lighting, its electricity bill would fall by 10% and air pollution would be reduced by between 4 and 7%. The Agency's Green Lights Program, initiated in 1991, has helped companies switch to energy-efficient lighting to save money and the environment.

There seems to be anecdotal evidence that low hanging fruit is abundant; so abundant that Michael Porter, in an article published in *Scientific American*, claimed that

> Strict environmental regulations do not inevitably hinder competitive advantage against foreign rivals, indeed, they often enhance it.
>
> (Porter, 1991 p.96)

That is, environmental policies are potentially win-win policies. They may prompt firms to see and pick low hanging fruit - a harvest for both the environment and for those firms.

The significance of what has become known as the "Porter Hypothesis" is that it apparently contradicts the conventional wisdom that environmental regulations shift formerly external costs back onto firms, burdening them relative to competing firms in countries with less strict regulations. Porter has subsequently elaborated on the hypothesis with many more examples (Porter and van der Linde, 1995), and others have taken up his argument, including senior officials in the US government (Gore, 1993).

The precise claim and meaning of the Porter Hypothesis are unclear because Porter's original examples mix several different ways by which the hypothesis could be true. The only one that is controversial, at least to mainstream economists, is the case where regulations purportedly reduce the absolute costs of the firms subject to them. It is controversial because it requires the existence of abundant low hanging fruit, and this in turn contradicts the neo-classical model of the firm.

If regulations are to lower the costs of firms subject to them, several conditions must occur. One is that firms are not productively efficient (they are not minimising private costs), *ex ante*. They are operating inside a cost efficiency frontier. Only from a starting point inside the frontier is it feasible to reduce simultaneously both social and private costs. All of this presupposes, in terms we have been using, that there is an organisational failure in the firm.

A second condition concerns the firm's behavioural response. Environmental regulations, while shifting external costs to the firm, must stimulate a sufficient improvement in productive efficiency to outweigh the internalised cost. Clearly, the existence of win-win opportunities neither assures that strict environmental regulations will help firms find them, nor that if found, they are valuable enough to offset the internalised costs. Win-win is logically most likely in situations where the firm is far from the efficiency frontier, where the burden of the compliance cost is light, and where the shift to the frontier can be made cheaply.

A final condition that is required for the hypothesis to be interesting to academics and practitioners is that it is systematically true. One can always find some anecdotal examples to contradict the simplifying assumptions of abstract deductive models. Porter apparently believes it is systematically and commonly true, even though he qualifies his statements with words like "may", "often", and "in many cases". Yet when he uses Japan and Germany as examples to argue that strict environmental policies have helped promote their productivity growth, he is clearly making a general statement.[7]

Porter's claim has spawned a number of papers, both pro and con, in business and academic journals. Most are anecdotal, some are theoretical, and a few are empirical. As examples, Meyer (1992) claims to find some statistical evidence in the US of a positive impact of environmental regulations on economic performance. Palmer and Simpson (1993 p. 17), by contrast, find Porter's arguments "based on unlikely assumptions and inconclusive

[7] The obvious alternative hypothesis is that the causality is reversed; that those countries' productivity levels and wealth caused their strict environmental regulations.

anecdotal evidence." Similarly, Oates, *et al*. (1994 p. 21) conclude that "Until such time as we acquire more compelling evidence on the Porter Hypothesis, it is our sense that it should not be given much credence." Walley and Whitehead (1994) believe that win-win opportunities exist but are rare. Jaffee, *et al*. (1995 p. 159) conclude their survey paper saying, "there is . . . little or no evidence supporting the revisionist hypothesis that environmental regulation stimulates innovation and improved international competitiveness."[8]

Procedures and routines in companies

> People are, at best, rational in terms of what they are aware of, and they can be aware of only tiny, disjointed facets of reality.
>
> (Simon, 1985 p. 302)

> The lengthy and crucial processes of generating alternatives, which include all the processes that we ordinarily designate by the word 'design', are left out of the [traditional] account of economic choice.
>
> (Simon, 1987)

> The way in which the organisation searches for alternatives is substantially a function of the operating rule it has. . . . The organisation uses standard operating procedures and rules of thumb to make and implement choices. In the short run these procedures dominate the decisions made.
>
> (Cyert and March, 1992 pp. 133-4)

We have already argued that the firm can be imagined as a principal who is linked to his or her agents by a network of systems and procedures. These systems, procedures, and routines are key features of any organisation. Cyert and March (1992) identified several types of procedures: task performing, record keeping, information handling, and planning. A critical function these procedures perform is to economise on limits to time and attention which curse us all but which are assumed away in traditional neo-classical modelling.

Because neo-classical economists assumed away these limits, company systems and procedures never had any significance to them. It was left to behavioural economists to examine rational choice by decision-makers with limited knowledge and computational abilities; decision-makers suffering from "bounded rationality" (see Simon, 1987).[9] This rendered management systems and procedures important to them, and as the reader will see, our approach follows their lead.

Let us imagine a decision maker in a firm facing a flow of questions, problems, or demands for decisions, each of which must be resolved not only in isolation but in relation to other parts of the organisation. Perhaps initially, in the process of learning a new job, he or she regards each event as unique and fashions a novel resolution for each. After some time, however, patterns emerge which make it possible to categorise incoming events according to standard types and to devise SOPs appropriate for resolving each type. These SOPs allow work to proceed much more quickly and efficient, but there will be errors introduced into the work from the inevitable mismatches between the actual events and their standardised types.

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[8] Although the majority of economists probably dismisses the Porter Hypothesis, at least as expressed here, it may have a redeeming political virtue of providing a counter argument to the business community's concern about cost of compliance with environmental regulations.

[9] The behaviouralists justified their assumption with empirical observations of human behaviour and the cognitive limitations that influence it.

By refining its SOPs or create new ones, a firm can reduce - although never eliminate - the mismatches between events and SOPs, but this will raise administrative costs.

This implies that the image of a firm setting each product's price by some idiosyncratic calculus of marginal costs and revenues is descriptively inaccurate. In reality, pricing decisions are standardised. They might be done, for example, by applying a fixed profit margin to standardised cost figures generated by a highly standardised cost accounting system. As Cyert and March (1992 p.124) observed, pricing decisions are "almost as routinised as production line decisions."

When one imagines a firm as a collection of systems, procedures, and routines, it becomes clear that one can introduce a concept of productive efficiency that is similar but not identical to that of neo-classical economics. The firm devises its systems in order to minimise operating costs. Those systems are rigid, however, so that once they are installed, they can act as a constraint on the firm's objective of profit maximisation. If the costs of that constraint are great enough, the firm can invest in changing the systems. Although the system constraint on profit maximisation is novel, the logic of cost minimisation and thus productive efficiency should be familiar to those schooled in neo-classical economics.

Less familiar is the fact that the firm constrained by its routines can make "mistakes". That is, the organisational constraint may prevent the firm from seeing and reacting to opportunities or threats that would be evident to an unconstrained firm.[10] This is what we call "organisational failure". The failure may be either an unwitting violation of the environmental laws and regulations or a missed opportunity to make a profit (that is, low hanging fruit left unpicked). It should be clear, however, that the term "organisational failure" does not connote that the firm is inefficient given its need for systems and procedures to economise on managerial time and attention.

Although we might suppose that the firm's systems, procedures, and routines are ideal when first devised, it should be clear that with the passage of time, they will become less and less so. Relative prices change, regulatory and other environmental conditions change, and the firm's competitive situation changes. If the procedures could be changed frequently, marginally, and at negligible cost, there should be no problem. Unfortunately, they cannot be. In the short run, they are essentially fixed. Paradoxically, the procedures that increase an organisation's efficiency also reduce its adaptability to changing circumstances.

The model of the insides of a firm that we have presented may be unfamiliar to traditional economists, but it is alive in the literature of organisational theory. Readers of that literature will encounter firms comprised of sets of systems, the elements of which must be congruent with each other and with the external environment (Nadler and Tushman, 1997; Tushman and O'Reilly, 1996). Expressed by Kogut and Zander,

> . . . the capabilities of the firm . . . rest in the organising principles by which relationships among individuals, within and between groups, and among organisations are structured.
>
> (Kogut and Zander, 1992 p.384)

It will be explained to readers that these systems coalesce in "quantum states" (Miller and Friesen, 1984). Tushman and O'Reilly (1996) call these "punctuated equilibria".

This organisational literature does not bequeath to us formal mathematical models of systems and procedures, quantum states, or punctuated equilibria. However, in economics there are mathematical models of analogous phenomena: technical compatibility standards

[10] In a mathematical maximisation model, this simply represents the reduced objective function value that the new constraint causes.

and the processes of shifting from one to another.[11] (For a survey of that literature, see David and Greenstein, 1990.) Explaining the analogies might help make the organisational literature comprehensible to those unfamiliar with it.

One analogy between technical standards and organisational systems is that both are a means of assuring compatibility between different elements of a system. Technical standards assure compatibility between software and hardware; organisational standards assure compatibility between design, production, and marketing or between the accounting system and the compensation system. Each possible outcome of the application of a set of procedures in one part of an organisation (that is, each standard solution to a routine problem) must be matched with procedures in many other parts. A related analogy is that any change in one standard requires co-ordination with many others or behaviour will not be controlled. Miller and Friesen (1984) implicitly recognise the analogy when they explain that movement between organisational quantum states cannot be made by changing each element of the system piecemeal but only by changing all simultaneously in a quantum leap.

This implies a third analogy. A change in organisational systems will be revolutionary, disruptive, and costly. It is like a miniature paradigm revolution in science about which Kuhn (1962) wrote. It is revolutionary in that the old systems are not pushed to evolve further but are destroyed to be replaced new ones. It is disruptive because agents must abandon traditional patterns of behaviour in which they have specific competencies and thus value to the firm, and they must learn new routines in their place. Clearly, agents may have a personal motive to resist this; the benefits of the change may be external to them. And it is costly. Apparent resistance to change may be more than just selfishness. Experimental evidence indicates that learning new routines is more difficult and costly when old routines must first be unlearned (Shiffrin and Schneider, 1977).

Inertia to change is a final analogy between technical standards and organisations. Inertia appears in models of conversion from an old technical standard to a new one (Farrell and Saloner, 1985, 1986), and organisational inertia is the dominant theme of organisation ecology and evolutionary economics.[12] Some sources of organisational inertia arise from human traits like myopia, hubris and denial (Rumelt, 1995). Others (closer to the focus of this paper) are "rooted in the size, complexity, and interdependence in the organisation's structures, systems, procedures, and processes" (Tushman and O'Reilly, 1996 p.18).

One may bemoan companies' reluctance to change systems, but one should note that this rigidity can be the penalty of success. Companies are often successful precisely because they have imbedded their routines so deep into their employees' consciousness and sub-consciousness that they become part of the company culture. To Nelson and Winter (1982), the skills and capabilities of an organisation are bound up in its routines. Indeed, one could argue that some companies amount to little more than their routines and the associated brand identity. MacDonalds is one obvious example; it is essentially the company's routines and the brand identity they have created that are franchised. IBM and Apple differ by much more than their product lines. Both firms succeeded for a long time in great part due to their routines, different though they were, and each eventually fell victim to the rigidity of its routines when a changing situation necessitated restructuring. General Motors is a widely cited example of a once-successful organisation nearly destroyed by its inertia. In the environmental domain, the Body Shop is best known not for its products but for a set of practices that support a philosophy embodying environmental virtue.

The rigidity they introduce into a firm is not the only - and possibly not the worst - curse of systems and procedures. They may also blind the firm to the changes that make those

[11] Compatibility standards are the technological or dimensional standards that allow different products to work together. Examples are standards for computer hardware and software, standards for audio or video hardware and software, automobile wheels and tires, etc.

[12] Organisation ecology posits that firms cannot change in any significant way; evolutionary economics accepts that they can, albeit with great difficulty.

same systems and procedures obsolete. As Cyert and March observed regarding procedures for record keeping,

> The records that are kept determine in large part what aspects of the environment will be observed and what alternatives of action will be considered by the firm.
>
> (Cyert and March, 1992 p.126)

Standard operating procedures and low hanging fruit

> [T]here is beyond question a body of very important but unorganized knowledge which cannot possibly be called scientific in the sense of knowledge of general rules: the knowledge of the particular circumstances of time and place. It is with respect to this that practically every individual has some advantage over all others because he possesses unique information of which beneficial use might be made, but of which use can be make only if the decisions depending on it are left to him or are made with his active co-operation.
>
> (Hayek, 1945 p.521)

> The 'facts of the case' may be directly present to the subordinate, but highly difficult to communicate to the superior. The insulation of the higher levels of the administrative hierarchy from the world of fact known at first hand by the lower levels is a familiar administrative phenomenon. . . . The information needed for a correct decision may be available only to the subordinate.
>
> (Simon, 1945 p.238)

Let us sketch a model that illustrates how the paradox of low hanging fruit can be explicated and how public policy might be fashioned to induce the firm to harvest it. In so doing, we will build on the previous sections which discussed the paradox, procedures and routines in companies, and our notion of organisational failures.

Organisational failures in an environmental context will be of two types. The first is a choice made or an action taken with a negative risk-adjusted expected value. This could be a violation of the environmental laws or some action that entails an excessive risk of causing an environmental accident for which the firm will be liable. The second is the failure to take a legitimate and profitable action (again in terms of a suitably risk-adjusted expected value). These are organisational failures because a rational and perfect black box firm would not make these mistakes, nor would a principle interested in maximising shareholder value. Note that the first (which we will call a type II error) is not necessarily an agent's calculated decision to break the law or risk an accident, nor is the second an agent's conscious neglect of profitable opportunities (a type I error). Rather, errors are inadvertent; they occur because information is imperfect, communication is costly, and human rationality is limited.

To model these errors, one must model a decision-making process within a firm. Imagine that a corporate principle is fashioning an environmental policy[13] for the corporate agents whose actions invariably entail risk of error. The objective of the policy is to reduce the probability of these errors. The principle must choose the form of the environmental policy. Let us imagine that there are two decision variables to it. One is vigour of effort. This can be measured in terms of direct cost for training agents, for providing them with information,

[13] The reader should note that in this paper, the term environmental policy is not necessarily public policy. The distinction between public and private (corporate) environmental policy will be clear in the context or it will be specified.

for staff to support them, and for auditing and monitoring the agents. Specific examples of such costs might include involvement with the EPA's Green Lights policy, compliance with EMAS or ISO 14000 requirements, and the cost of introducing green accounting systems. Presuming these efforts are effective, they should reduce organisational failures of both types.

The second decision variable is the constraint on agents' decision-making latitude. Two basic means are available to do this: SOPs and centralisation of authority. Either one denies agents the ability to make ad hoc decisions. Although they are different means, they have the same consequences for the model we are developing, and we will speak from here on about SOPs. The reader may substitute centralisation at will. As suggest by the quotations that introduce this section, to constrain agents' decision-making latitude may reduce the likelihood of a negligent act, but it will result in the loss of opportunity to profit from "information . . . available only to the subordinate."

Although these two approaches are not inconsistent, they are likely to be substitutes. If agents' decision-making latitude is constrained by SOPs (or if the decisions are made closer to or even by the principal), then it is less necessary to disseminate information to agents and to audit their actions.

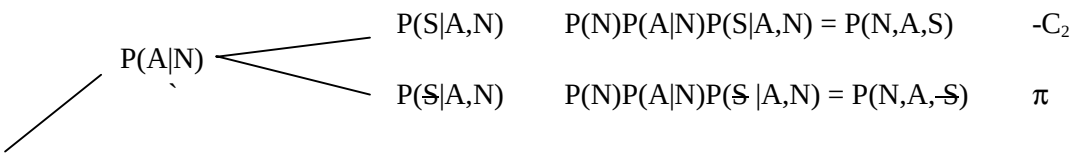
With this basic outline, we can model the firm as follows.[14] Agents face a flow of possible choices in their work. As regards those choices with environmental implications, some would be truly negligent. In the model following, let P(N) be the probability that any contemplated choice is inherently negligent, regardless of whether the firm makes the choice and regardless of whether it is detected if it does. The probability that negligence is actually committed, by contrast, is the product of P(N) and the conditional probability that the firm embarks on the course of action, given that it is negligent (P(A|N)). Ex post, this may cause the firm no loss, and it may even earn a profit. Nonetheless, the expected value is negative because of the probability of detection, either by the enforcement authority's investigation or because of an actual environmental accident. The probability of detected negligence is the probability that a negligent act is committed multiplied by the conditional probability that if committed, it is discovered (P(S|A,N)). In this case, the firm faces a cost of compensation, perhaps environmental restitution, and punitive damages.

Not all accidents are the result of negligence, of course. It is always possible that an action that is not negligent in a legal sense can cause an accident. This probability would be given by P(S|A,~~N~~). If such should happen, the firm may have to compensate harmed parties, but this cost is naturally lower than that of a negligent accident.

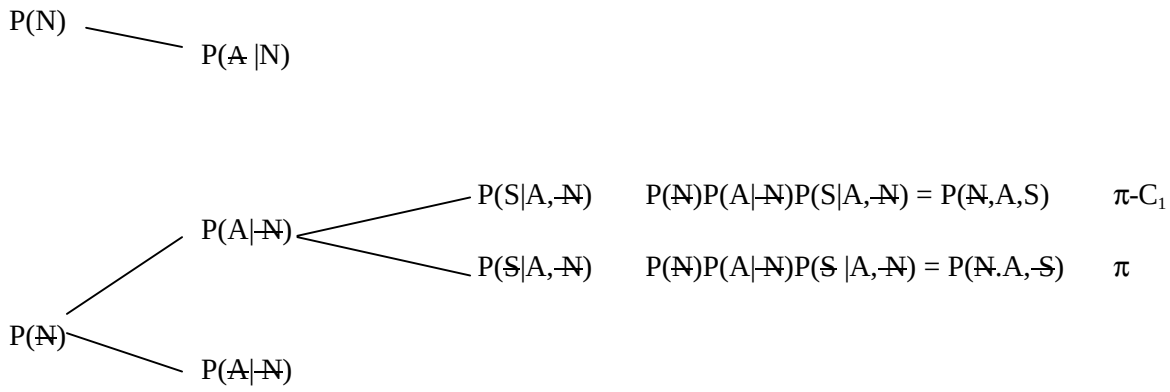
Finally, the agents may inadvertently choose not to take advantage of a legitimate opportunity to save environmental resources. This is the mistake of leaving low hanging fruit on the tree, and it entails a certain lose of the potential profit. In terms analogous to those above, P(~~A~~|~~N~~) is the probability that a legitimate course of action is not followed (a type I error).

The decision tree is shown in Figure 1.

Figure 1. Decision tree



[14] This model is adapted from Beckenstein and Gabel (1986).



So the firm's principal must design an environmental policy to maximise an expected return, E(R).

$$E(R) = \{P(N,A,\text{~~S~~},) + P(\text{~~N~~},A,\text{~~S~~})\}\pi - P(N,A,S)C_2 + P(\text{~~N~~},A,S)(\pi - C_1) - C_3 \quad (1)$$

where:

P(N,A,~~S~~)	the probability that a negligent action is taken but not detected
P(~~N~~,A,~~S~~)	the probability that a legitimate action is taken
P(N,A,S)	the probability that a negligent action is taken and detected
P(~~N~~,A,S)	the probability that a non-negligent action results in an environmental accident
C_1	compensation and damages from a non-negligent accident
C_2	punitive fines, damages, compensation and other costs from a negligent accident ($C_2>C_1$)
C_3	cost of training and monitoring agents
π	the profit earned from a legitimate action taken or a negligent action that is not detected

The expected return can be simplified by converting the joint probabilities into conditional probabilities and expressing them as the type I and II errors discussed above.

f = P(~~A~~|~~N~~)	the probability that the company will make a type I error, that it will leave low hanging fruit unpicked
g = P(A|N)	the probability that the company will make a type II error; that it will take a negligent action
m = P(S|A,~~N~~)	the probability that a non-negligent action results in an environmental accident
n = P(~~S~~|A,N)	the probability that a negligent action causes no accident

then,

$\alpha = (1 - n)\, C_2 - n\pi$ the company's expected cost of a negligent action ($\alpha > 0$)

$\beta = \pi - m\, C_1$ the company's expected benefit of a legitimate action ($\beta > 0$)

The requirement that α and β be positive implies, consistent with the text, that a rational actor would neither be purposefully negligent nor overlook a profitable action.

The expected return can now be rewritten as:

$$E(R) = - P(N)g\alpha + P(\cancel{N})(1 - f)\beta - C_3 \quad (2)$$

The decision variables for the principal are the expenditure on training, information, and monitoring, C_3, and a continuous variable X that measures the extent of SOPs controlling the agents' behaviour. A high value of X will denote extensive SOPs (or centralisation). These two policy variables determine the type I and II error probabilities, f and g, with partial derivatives shown in Table 1.

$$f = f(C_3, X) \quad (3)$$

$$g = g(C_3, X) \quad (4)$$

Table 1. Partial derivatives

$f_c < 0$	$g_{cx} > 0$
$f_x > 0$	$f_{cc} > 0$
$g_c < 0$	$f_{xx} < 0$
$g_x < 0$	$g_{cc} > 0$
$f_{cx} < 0$	$g_{xx} > 0$

An increase in C_3 should simultaneously reduce both f and g, the company's type I and II error probabilities. By contrast, an increase in X, the extent of SOPs, should reduce type II errors but increase type I errors as agents are less able to exploit their knowledge of the uniqueness of each situation. The signs of the second derivatives are based on the idea of diminishing marginal effectiveness of the policy instruments. Presumably, steps with the greatest impact will be taken first. The assumption about the cross-partial derivatives rests on the notion that the marginal effectiveness of an instrument in reducing one error type is lessened to the extent that the other instrument has already reduced that error.

The principal will maximise E(R) by varying C_3 and X. The first order conditions can be solved for a maximum to give C_3^* and X^*, the optimal corporate environmental policy.

The manager's objective is to maximise E(R) in equation (2) by varying C_3 and X with error probabilities implied by equations (3) and (4). First order conditions for a maximum are:

$$\partial E(R)/\partial C_3 = - P(N)g_c\alpha - P(\cancel{N})f_c\beta - 1 = 0 \quad (5)$$

$$\partial E(R)/\partial X = - P(N)g_x\alpha - P(\cancel{N})f_x\beta = 0 \quad (6)$$

The two first-order conditions can be solved to give C_3^* and X^*, the profit-maximising values of C_3 and X.

Second-order conditions required for a maximum are:

$$P(N)g_{cc}\alpha + P(\cancel{N})f_{cc}\beta > 0$$

$$P(N)g_{xx}\alpha + P(\bar{N})f_{xx}\beta > 0$$

and

$$\{P(N)g_{cc}\alpha + P(\bar{N})f_{cc}\beta\}\{P(N)g_{xx}\alpha + P(\bar{N})f_{xx}\beta\} - \{P(N)g_{cx}\alpha + P(\bar{N})f_{cx}\beta\}^2 > 0$$

The first two inequalities hold from our earlier assumptions. The third cannot be guaranteed, however. It simply describes a condition that must exist if there is to be a profit-maximising equilibrium.

Comparative static analysis gives the signs shown in Table 2.

Table 2. Signs of comparative static results for the corporation

	endogenous variable			
exogenous variable	C_3^*	X^*	f	g
C_1	(-)	(+)	(+)	(?)
C_2	(+)	(+)	(?)	(-)
m	(-)	(+)	(+)	(?)
n	(-)	(-)	(?)	(+)
π	(?)	(-)	(?)	(?)

This model shows that by endogenising the firm's compliance policy, we can get an insight into several phenomena not otherwise revealed. We see that there is always a positive probability of environmental accidents, negligent and otherwise. C_3 is increased only until it becomes uneconomic and not until there are no longer any errors. The same is true for X. We see, as well, that there is always low hanging fruit on the tree.

Comparative static analysis shows that an increase in the cost of accidents or the probability that negligence is detected and punished will prompt an adaptation in corporate environmental policy, and that the form of adaptation depends on the precise nature of the accident.

For example, if penalties for a negligent act are increased, the principal will adapt policy by increasing the training and monitoring of agents and by increasing the SOPs which constrain agents' discretion. This will unambiguously lower the risk of an environmental accident since both forms of corporate policy response act in the same direction. The impact on the amount of low hanging fruit left on the tree is ambiguous, however. The reason is that the two forms of response have opposing effects on the probability of type I errors. More training, monitoring, information, support staff, green accounting, etc. will make managers more conscious of the environment generally, and they should pay more attention to low hanging fruit as a result. But more standardised procedures will have the opposite effect.

The result described above will also occur if the environmental enforcement agency becomes more diligent in enforcing its policy and raises the likelihood that negligence is caught.

If we are to examine Porter's hypothesis that environmental policy may affect the likelihood that low hanging fruit is picked, we have to examine the environmental authority's policy options. It can, of course, vary the penalties for a negligent accident or a detected violation. Let us assume that in addition, it can determine restitution or cleanup costs and that it has discretion to award damages to harmed parties even if an accident was not negligent.

If more strict environmental policy is to reduce environmental accidents while at the same time encourage firms to pick and profit from low hanging fruit, then it must prompt a

specific reaction from the firm. It must cause fewer SOPs and more decision-making latitude for agents, while at the same time increasing the training and support given to the agents to help them in their decision-making. The results of comparative static analysis show that this will occur if enforcement policy combines two elements: heavier penalties for negligence (higher C_3) and lower costs for the firm on the occurrence of an accident in which there was no negligence (lower C_1). In the limit, this would argue against rules of strict liability in lieu of increasing penalties for negligence.

The firm's adaptation process works as follows. Heavier penalties for negligence raise both C_3 and X which reduces the probability of an accident but has an ambiguous impact on low hanging fruit. A reduction in damages for a non-negligent accident also raises C_3 but lowers X, reinforcing the reduction in the probability of a negligent accident. The other consequence, however, is that the principal will reduce SOPs. This reinforces the impact of higher spending on training and monitoring on type I errors, and it should reduce low hanging fruit.

To demonstrate the Porter Hypothesis, we must still show that the adaptation process described can increase E(R), the firm's expected return. To do so, we substitute the first order conditions (5) and (6) into the objective function (2) to get the expected returns to the firm when corporate environmental policy is optimal.

$$E(R) = \{P(N)\beta f_c + 1\}g/g_c + \{-P(N)\alpha g_x\}(1 - f)/f_x - C_3 \qquad (7)$$

We can then take the total derivative of (7) with respect to C_1 and C_2. If the signs are not unambiguously positive with C_1 and negative with C_2, then the Porter Hypothesis is feasible. Note that we do not intend to show that Porter is necessarily right; we do not require that the two signs be respectively negative and positive. We only need show that the hypothesis is feasible.

The first term to the right of the equality in (7) comprises the cost of negligent actions, net of gain from those that do not result in accidents and thus by assumption are not detected. The second term comprises the returns to the firm from legitimate actions, net of the cost of those that cause accidents. The final term is the cost of training and monitoring.

Not surprisingly, some of the elements of the total derivative of (7) are ambiguous in sign, and in composition there are offsetting impacts which render the overall signs ambiguous.[15]

We can summarise the results first with respect to an increase in fines and penalties for negligence.

(a) This will have an ambiguous impact on the total cost to the firm of negligent acts. It will increase SOPs' restraint on agents' decision-making, and it will increase spending on agents' training and monitoring. Both of these work in consort to reduce the frequency of negligent actions, but not necessarily enough to offset the higher cost of each single negligent act.
(b) It has an ambiguous impact on the cost to the firm of low hanging fruit since SOPs increase it while training reduces it.
(c) There will be an unambiguous increase in training and monitoring cost to the firm.

A reduction in costs for non-negligent accidents will have the following consequences.

(a) It will have an ambiguous impact on the cost of negligent acts since there will be more discretion for agents (fewer SOPs) coupled with increased training and monitoring.

[15] To simplify signing the expression, we assume that all the second-order derivatives are negligible compared to the other terms. They are set to zero.

These two organisational changes have counteracting effects on the probability of a negligent act.

(b) There will be a certain increase in the firm's returns from legitimate actions because both the reduction in SOPs and the increase in training reduce low hanging fruit. This will be supported by the lower costs of non-negligent accidents noted above.

(d) There will be an unambiguous increase in training and monitoring cost to the firm.

In conclusion, stricter environmental policy (interpreted here as a policy change that increases the penalties for negligence and reduces the frequency of accidents) may increase a firm's returns by reducing its absolute costs. That is, it may fit results Porter hypothesized.

Further instruments

We will discuss below several additional instruments that might be of use. This is surely not an exhaustive list, but it is our attempt to show at least some of the major alternatives.

The compensation system

In Gabel and Sinclair-Desgagne (1993), we explored the extent to which an incentive-based compensation system could be used to deal with a multi-task principal-agent problem. The model we presented in that paper was one in which an agent allocated a limited amount of effort between two tasks. One task earned profit for the firm and the other task reduced the risk of an environmental accident. The principal wanted to control the agent's allocation of effort between the tasks, but that allocation was not observable. The principal could only infer the agent's effort from some imperfect measure of performance on each task. So in this model, there was costless but imperfect and indirect monitoring of the variable of interest - the agent's effort. The question we posed was whether the principal should link the agent's compensation to the measure of performance on environmental risk reduction.

We found from the model that when the agent's effort constraint was not binding, then it was optimal for the principal to use an incentive wage to reward performance on environmental risk reduction. Furthermore, the slope of the optimal performance-wage schedule for either task was proportional to both the principal's eagerness to influence performance on the task and to the relative accuracy of the principal's measure of the agent's effort expended on it. In this model, monitoring technology and accuracy were exogenous.

If the agent's effort constraint were binding, however, then it may not be efficient for the principal to pay an incentive wage based on measured performance on environmental risk reduction. This rather surprising result has an intuitive rationale. If the effort constraint were binding, interaction between the principal and the agent would be limited to risk sharing, but efficient risk sharing requires that the marginal rates of substitution between the various income levels be equal. This could only be achieved if the wage schedule were invariant in the measure of risk reduction.

Auditing non-financial objectives

In the model described above, monitoring was free, and its technology and accuracy were exogenous. In reality, every monitoring system is costly, and if the principal were to spend more, he or she could usually improve the system's accuracy. That is, accuracy should be endogenised. So a pertinent question to ask is how the principal should make the optimal joint decision on the level of monitoring of effort on the non-financial environmental objective and the compensation for both tasks. (Monitoring financial performance is also important, of course, but one can assume that it is done routinely irrespective of environmental concerns.)

Intuitively, monitoring would enter the principal's utility function as a cost along with the contingent wage. The principal would then maximise over the two control variables - the wage and the expenditure on monitoring. The agent's utility function would presumably be unchanged.

The benefit to the principal of greater expenditure on monitoring is that it would improve the accuracy of his or her inference of the agent's effort on environmental risk reduction. With more precision here, the principal would increase the slope of the performance-wage gradient. This would shift more of the risk of an environmental accident to the agent, and the agent would adjust by dedicating more effort to that activity, ceteris paribus.

A further benefit of spending more on monitoring is that it would improve the principal's assessment of whether the effort constraint on the agent was binding. As explained above, the choice of a salary system depends on this assessment. Once the quality of monitoring is endogenised, a linkage can be modelled between the cost of monitoring and the cost of a mistaken salary system.

In Sinclair-Desgagné and Gabel (1997), the authors used a multi-task, multi-signal principal-agent model to look at the optimal design of environmental audits and the manager's consequent allocation of effort. They showed that where managers had discretion on how to distribute their effort between standard business duties and environmental protection, the occurrence of environmental audits and the optimal wage structure should depend on the importance of the managers' prudence (or precautionary motives) relative to their aversion to risk. When prudence dominates risk aversion, environmental audits should be triggered by high financial assessments, and the wage of an audited manager should go up on average. When risk aversion dominates, however, environmental audits should be held if financial assessments are low, and the expected compensation of an audited manager should be lower than the wage when no audit occurs. These results therefore predict that environmental audits will happen more frequently when managers' attitude toward risk is strongly driven by precautionary motives, because in this case such audits constitute a reward rather than a punishment.

Internal pricing

There are alternatives to assigning an agent multiple and potentially conflicting financial and non-financial tasks. One is for the principal to try to correct the firm's system of internal accounting prices to reflect all implicit values of the firm. If the firm were to internalise all externalities to the agent that are borne by the principal, then decentralised decision making within the firm would again be optimal to the principal. With the measure of performance on both tasks reduced to a single financial criterion, there would be no conflict between the tasks. But how could this be done?

Note that this problem is similar to, but not the same as, the familiar transfer pricing problem. The transfer pricing problem is commonly portrayed as one of finding the price for intra-firm trade that comes closest to inducing an efficient level of that trade. Presuming no exogenously available reference price, the challenge is to design an incentive mechanism to tease the correct price out of those in the firm who know it. The problem we describe here is again one of getting correct intra-firm prices, but there is no *prima facie* argument that individuals know the correct prices but have an incentive to conceal them. Rather, the principal must construct truly unknown prices (or their expected values) from data that are costly to collect.

There are many examples of companies that have attempted to improve their environmental performance via this means. Naturally, environmental audits are a frequent starting point since one of their goals is to gather data on actual and potential environmental costs facing the firm. One example is that of a European chemical producer that attempted to identify all environmental costs allocated to its overhead accounts and then to shift those costs to the products or processes that truly generated them. For example, insurance premia

and legal fees incurred or expected were charged to specific production centres or products. With altered costs and product margins caused by these additional charges, production and sales managers' incentives to favour environmentally benign options increased. In a similar vein, products whose use might create future liabilities, legal or just in terms of image, could be "artificially" burdened by accounting charges reflecting that risk (Epstein, 1996a,b,c). Feeding back through an incentive system based on profit, such products would be shunned in favour of environmentally favourable alternatives.

Another example appeared some years ago in the US steel industry. The EPA experimented with intra-firm emissions trading in the early 1980s. That allowed Armco Steel to employ linear and integer programming models (Bodily and Gabel, 1982) to calculate the shadow price of its particulate effluents. Then the company charged its many facilities with their use value. Re-optimisation earned the company a saving of $50 million annually. Although Armco dealt with emissions entitlements as an idiosyncratic experience, firms that become accustomed to emissions trading should build entitlement values into their formal cost accounting systems.

A further example of the spirit of this corporate policy is the effort of automobile producers to design models on the basis of an assumption that the makers would be responsible for repossessing the cars at the end of their lifetimes. With the costs of recovery, re-manufacturing, recycling, or ultimate disposal imposed on design teams, the cars should emerge at least somewhat less environmentally pernicious. This example suggests a role for life-cycle analysis. Unlike environmental audits which look at the firm per se, life-cycle analysis, despite all its methodologically and practically inadequacies, looks upstream and downstream of the firm. With life-cycle analysis, firms can apprise themselves of the otherwise invisible costs that they may find themselves unexpectedly bearing.[16]

Although this is a simple look at internal pricing, at a more subtle level, problems of impacted information and perverse incentives may assert themselves. For example, if intra-firm prices are "corrected" for costs incurred by the principal but previously external to the agent, should the agent have the option to subcontract work to other firms? One can assume that there are external costs there, too, and that some of them may be borne by the principal. Under these (reasonable) assumptions, it is clear that questions of transfer pricing are not independent of questions of organisational form. Those questions could range from centralisation vs. decentralisation of decision making all the way to integration vs. specialisation of the firm's activities. This suggests the relevance of work such as that of Holmström and Tirole (1991) which attempts to integrate transfer pricing and organisational form. The authors admit that their work is exploratory and at this stage cannot offer specific predictions, but the questions it poses are relevant to environmental resource management. How much flexibility should units in the firm have? Is the opportunity cost of trading outside of the firm large or small? Is monitoring of outside trading relations feasible, and if so, at what cost?

This is not an artificial problem, and the oil industry provides an example of it. A diversified oil company could burden its shipping division with the insurable and non-insurable costs of many kinds that the corporation, as distinct from the division, would expect to incur should there be an oil spill. The intent would be to ensure a correct incentive for the shipping division to undertake risk minimising actions (like operating vessels with double-bottomed hulls). But once those costs were allocated, the division might decide to subcontract some of its shipping (e.g., that in US waters where the legal liability for a spill is especially great) to small independent firms protected by their limited liability. Should this be permitted?

Precisely this question arose after the Exxon Valdez accident. Seeing the enormity of Exxon's legal liability and loss of reputation, Shell Oil's transport division ceased commercial tanker operations in US waters and contracted it to small shippers instead. Other

[16] Of course, if all prices were correct in the first place, then there would be no need for a life-cycle analysis.

oil companies refrained from following Shell's lead, and presumably employed other control systems instead. Yet a systematic model to examine these alternatives is still missing.

Horizontal task restructuring

Another alternative to assigning potentially conflicting profit and environmental risk reduction responsibilities to a single agent is to assign the different tasks to different agents. This, like internal accounting reforms, would obviate the problem of designing a reward system to control how one agent allocated his or her effort. In essence, the amount of effort dedicated to the different tasks is centralised with the principal who decides on the number of agents assigned to each. But there is still the problem of how to define the tasks and how to structure the incentives for them.

Holmström and Milgrom (1990) argue that tasks for which performance is relatively easy to assess should be assigned to one manager, while tasks that are inherently difficult to monitor should be assigned to another. The former's compensation should be incentive-based while the latter's should not be. It seems reasonable to assume that direct profit-making tasks are relatively easy to monitor while it is inherently difficult to monitor non-financial environmental tasks. It follows that profit and loss objectives should go to one agent while environmental performance should be the domain of another. The former should face an incentive compensation scheme and the latter not. This match between monitoring accuracy and compensation scheme is consistent with our results in the single agent, multi-task problem referred to above.

The match is also consistent with commonly observed business practice. Firms often have line managers with profit and loss responsibility working under strong incentive salary plans based on financial measures, while staff responsible for environmental affairs have salaries de-coupled from operating profit. Under such an organisational arrangement, the environmental staff may be responsible for making capital investment decisions (with a budget allocated centrally) intended to reduce environmental effluents or risks.

Corporate sanctions of agents for negligence

Segerson and Tietenberg (1992) used a principal-agent model to analyse the issue of corporate vs. individual legal sanctions for violations of environmental laws. A related issue is that of corporate-imposed sanctions for agents guilty of violating company environmental policy (whether or not the violation caused environmental damage).

It is common for companies exposed to the risk of environmental liability to attempt to shift some of it to the employees whose negligent actions may incur that liability. This can be done by threatening dismissal, for example, or by stating in the employment contract that legal aid and the indemnification of fines would be denied to any employee found personally and negligently liable for an environmental accident.

In the context of a model, liability cost functions dependent on the damage caused or the seriousness of the breach of company policy would have to be specified for both principal and agent and then subtracted from their respective utility functions. Furthermore, a conditional probability of an environmental accident given the agent's action would have to be specified.

Unfortunately, if principals punish agents for mistakes, the agents may try to hide those mistakes. There are many instances in which immediate reporting of mistakes can allow the principal to mitigate both their social and private costs. In fact, prompt disclosure of environmental accidents is enshrined in the United Nations guidelines for transnational corporations (United Nations Centre on Transnational Corporations, 1991). Are there ways by which a balance can be struck between a motive to punish negligence and a desire for immediate reporting?

Wathieu (1993) addressed this question in a formal principal-agent model. He showed that it was possible to set up an incentive scheme to induce self-reporting if the scheme entailed a penalty that diminished with the agent's time horizon. The penalty was always below the agent's liability constraint, and it was progressively more so with a decrease in either the agent's discount rate or the precision of the principal's ability to estimate the delay in reporting. With an increase in monitoring frequency, the size of the penalty can diminish. Rather unexpectedly, Wathieu showed that it was possible that the optimal company fine could be negative - i.e., that the principal should reward the agent for reporting his or her own negligence. Despite the premium, however, the overall payoff to the agent of a mistake must still be negative (from the exogenous liability cost).

Conclusion

We have tried in this paper to convince the reader that relative to spending more research time looking at market relationships between firm, there is a very high return to looking at what happens inside a firm. Many of the tools to do so exist in the repertoire of the economist, and complementary tools and concepts are on offer in other disciplines, especially organisational science. We believe that the return is more than academic. Managers are under pressure to improve the environmental performance of their companies, and our impression is that serious thinking about how they can do so is only beginning. Once they write the corporate policy statement to the effect that they will respect the environment and be good citizens, most managers have little idea how to proceed; little idea how to translate their goal for the company into systems of incentives and controls to achieve it. Public policy-makers have profited enormously from the work of academic economists over the years. Company policy-makers need help, too.

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