The Benefits of Improved Environmental Accounting: An Economic Framework to Identify Priorities

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Abstract

Improved environmental accounting is increasingly seen by corporate managers and environmental advocates alike as a necessary complement to improved environmental decision-making within the private sector. This paper develops an economic approach to the evaluation of environmental accounting's benefits and derives the value, and determinants, of improved accounting information in several production and capital budgeting contexts. Using concepts from managerial economics, finance, and organizational theory, the analysis identifies the types of environmental accounting improvement that are most likely to yield significant financial and environmental benefits.

Key Words: environmental accounting, capital investment, corporate decision-making

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THE BENEFITS OF IMPROVED ENVIRONMENTAL ACCOUNTING: AN ECONOMIC FRAMEWORK TO IDENTIFY PRIORITIES

James Boyd*

1. INTRODUCTION

> *"A successful environmental management system should have a method for accounting for full environmental costs and should integrate private environmental costs into capital budgeting, cost allocation, process/ product design and other forward-looking decisions ... Most corporate information and decision systems do not currently support such proactive and prospective decision making." (EPA, 1995a)*

Improved environmental accounting (EA) is seen by corporate managers and environmental advocates alike as a necessary complement to improved environmental decision-making within the private sector. Whether the goal is pollution prevention, or some broader notion of "corporate sustainability," there is a widespread belief that sound environmental accounting will help firms identify and implement financially desirable environmental innovations. Moreover, environmental regulation is evolving toward public policies that rely to a much greater extent on the collection and reporting of environmental information.

This paper develops an economic approach to the evaluation of environmental accounting's benefits. Using concepts from managerial economics, finance, and organization theory, the value of improved environmental accounting information is explored. The overall goal is the identification of priorities for improved environmental accounting. Given the difficulties and costs associated with adopting new accounting methods and the collection and verification of data, it is desirable to identify situations in which the benefits of improved information are likely to be greatest. As will be shown, "better" information is not always valuable. Analysis of corporate decision-making and the value of information to the decision-making process is an important first step if private sector managers (and regulators) are to set priorities for improved environmental accounting.

An expanding literature documents problematic accounting practices with the potential to bias environmental decision-making (EPA, 1995b). Frequent targets for criticism are the allocation of environmental costs to general overhead accounts, the failure to account for future contingent liabilities, and the failure to measure the impact of environmental decisions on corporate image and customer and supplier relationships. From a public policy

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perspective, poor environmental accounting means that the private sector is likely to "miss" investment, procurement, and process and product design opportunities that have financial and environmental benefits. It is widely believed that improved environmental accounting practices, working in conjunction with the private sector's own profit motives, will create significant environmental benefits. This perspective has in turn motivated a growing literature on financial and accounting methodologies to improve accounting practices (Moilanen and Martin, 1996; Epstein, 1996).[1]

Regulators to date have opted for a relatively "non-interventionist" approach to environmental accounting reform. The U.S. Environmental Protection Agency, for instance, through surveys and case studies, has identified weaknesses in private sector environmental accounting and promotes the diffusion of accounting "best practices." This outreach- and communication-based approach may be expanded upon in the future, however. There currently are calls from some environmental advocates for more aggressive regulatory actions in this area, such as mandated environmental accounting. And several states have commenced experiments in this area. Pollution prevention statutes, in particular, are seen as a potential legislative vehicle for mandated environmental accounting.[2]

Yet, despite progress in the identification of problems and the development of improved methodologies -- and the possibility of regulatory initiatives that feature mandated environmental accounting -- the field lacks a methodology for evaluating the social and private benefits of improved environmental accounting. Whether regulators continue to motivate EA indirectly via outreach to the private sector, or more directly via incentives such as tax breaks or mandates, private sector resources and regulatory attention should be focused on initiatives that promise the greatest benefit.

Within the private sector, one would be hard pressed to find a manager who would disagree with the proposition that more accurate, detailed information is desirable. After all, better information inarguably leads to better (i.e., more profitable) decisions. The difficulty -- and undoubtedly an explanation for the relatively slow pace of change within the corporate sector -- is that better information is always costly to acquire, maintain, and verify. Given costs and the organizational inertia that inhibit changes in accounting practice, regulators and EA advocates should seek and advertise change where the value of better EA is highest. Currently, firms are being told to amend their practices, and may wish to do so themselves, but are being given much less direction on the changes that are likely to be most beneficial to them.

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[1] For case studies of environmental accounting's practical application to corporate environmental decision-making see Boyd (1998), EPA (1995c), and Tellus Institute (1996).

[2] Washington State and New Jersey have enacted the prominent examples of statutory pollution prevention requirements that feature an environmental or "materials" accounting component. See Schuler (1992) for a description of the 1991 New Jersey Pollution Prevention Act. There is a distinction between environmental and materials accounting in that materials accounting focuses on physical, rather than financial measurements. The distinction, however, should not obscure the movement toward mandated collection and reporting of facility- and process-specific data.

All of this highlights the desirability of a framework that will identify priorities for improved environmental accounting. This paper derives such a framework by exploring the determinants of the value of information in a corporate decision-making context. The paper proceeds as follows. The next section defines environmental accounting and the meaning of "improved" information, and discusses the costs associated with those improvements. Section 3 describes the economic value of information in general terms. Section 4 applies the value of information framework to a model of production process decision-making and Section 5 discusses applications in the capital budgeting context. Section 6 highlights a set of considerations that should guide the search for environmental accounting priorities. Section 7 concludes.

2. ENVIRONMENTAL ACCOUNTING

Before turning to the analysis of environmental accounting's benefits it is first important to define environmental accounting itself, as well as the meaning of "better" accounting methods and data.

2.1 The Definition of Environmental Accounting

Environmental accounting is a term with a variety of meanings. In many contexts, environmental accounting is taken to mean the identification and reporting of environment-specific costs, such as liability costs or waste disposal costs. For the purposes of this analysis, a much more general definition is used. "Environmental accounting" is more than accounting for environmental benefits and costs. It is accounting for *any* costs and benefits that arise from changes to a firm's products or processes, where the change also involves a change in environmental impacts. As will be shown, improved accounting for non-environmental costs and benefits -- input prices, consumer demand, etc. -- can lead to changes in decision-making that have environmental consequences. Thus, we will de-emphasize any clear demarcation between "environmental" accounting and accounting generally.

Environmental accounting information need not be the product of accountants, nor need it be used by accountants. Instead, it is any information with either explicit or implicit financial content that is used as an input to a firm's decision-making. Product designers, financial analysts, and facility managers are equally likely to be the users of environmental accounting data. Almost any type of information collected and analyzed by firms will qualify. Examples include input prices, technical and scientific studies that relate production processes to physical outputs, and legal, marketing, and financial analyses.

2.2 The Definition of "Improved" Environmental Accounting

Environmental accounting can be considered improved if it yields information that is better in one of the following senses: First, and most intuitively, information is better if it corrects a pre-existing inaccuracy. As an example, consider the use of an input that is highly toxic. It would be inaccurate to view the cost of the input as equivalent to its bulk supply cost alone. Environmental accounting provides better information if it attaches a cost to this input that captures the expected cost of environmental and workforce hazards.

Second, information should be thought of as better if it reduces the uncertainty surrounding some future cost or benefit. For instance, future liabilities are inherently uncertain. Information that can narrow the variance on estimates of those uncertain liabilities should be considered better information. Reduced variance is particularly valuable when decision-makers are risk-averse, since a reduction in variance alone can lead to different decisions when there is risk aversion. If decision-makers are risk neutral (basing decisions purely on the expected value of an uncertain parameter), reduced variance has no effect unless it is accompanied by a change in the parameter's expected value.[3]

Third, information is better if it is more highly disaggregated (more detailed). For example, data on wastes produced by individual processes or product lines is better than data on wastes created by an entire factory. For instance, accounting that assigns a wide variety of costs to overhead is problematic because of a lack of disaggregation. Disaggregation is necessary to incremental financial analysis -- i.e., the evaluation of investment or production opportunities based on their incremental costs and incremental contributions to revenue. Without disaggregation it is more difficult for managers to differentiate between substitutes and identify the true cost of producing a product. In turn, this inhibits optimal decision-making.

The above improvements relate to the collection and application of data in decision-making. Better environmental accounting may also relate to the use of improved managerial accounting techniques, such as adjustments for risk, discount rates, and appropriate time horizons for cash flow analysis.

2.3 The Costs of Better Information

This analysis takes as given that improved information and accounting methods are costly. While costs will vary across different types of improved information -- and are by no means always easy to measure -- they are conceptually straightforward to define. Information's costs include the labor and capital costs necessary to acquire, apply, and verify new information. The costs may be associated with a diverse set of activities, including technical R&D, financial analysis, process engineering studies, software development, inventory controls, and supplier surveys. Depending on the way in which information is used, its costs may either be fixed or marginal, one-time or recurring. The analysis of net benefits requires attention only to the incremental costs of information. For example, if input price data is already collected by a firm, the cost of applying that data to environmental decision-making is simply the cost of transferring the already-collected data to a broader set of decision-makers.

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[3] A truncation of possible outcomes can both reduce the variance of an uncertain parameter and change its expected value. For instance, if we initially believe a price, with uniform probability, lies somewhere between $0 and $100 and then learn that the price must be at least $20 (so that there is now a uniform probability of the price being between $20 and $100), we have both reduced variance and increased the expected value of the price.

3. THE VALUE OF INFORMATION

Information -- or more precisely, better information -- can be viewed much like any other commodity in that it is costly to acquire and provides benefits to the user. The goal is to identify the kinds of situations in which improvements in data or methods are likely to yield the greatest net benefit. From an economic standpoint, information itself has little intrinsic value. Instead, information acquires value when it facilitates optimizing behavior. That is, better information can lead to changes in actions, changes that themselves create value.

Consider a common form of valuable information: a weather forecast. Farmers find weather forecasts valuable because they provide information that is useful in determining the best time to plant or harvest crops. Three things are necessary, however, for a forecast to have value. First, the farmer must have the flexibility to alter the timing of planting or harvest. Second, the forecast must reveal information different from the farmer's expectations prior to the forecast. Note that, together, these conditions imply that *information has value only if it leads to decisions different from those that would be made in the absence of the information*. Third, the change in farming strategy that results from the forecast must have economic value, say, due to a larger harvest.[4]

3.1 A General Framework for Valuing the Benefits of Improved Information

The above discussion highlights three conditions necessary for the forecast to have value. These three conditions hold more generally and form the basis of a framework to analyze the benefits of improved environmental accounting information. In order to place a value on improved information it is necessary to understand the following:

- The scope of alternative actions available to firms. In general, the wider the scope of alternatives, the greater is the potential value of changed decisions in response to new information. Alternative actions can take the form of changes in output, input substitution, and delayed or accelerated investment.
- Prior beliefs and the likelihood that new information will change those beliefs. Information will tend to be more valuable, the greater are the uncertainties and inaccuracies to be resolved by better information.
- The financial value gained by changing a decision in response to the new information.

These concepts suggest a framework for analysis. First, the firm or regulator must define the improved accounting procedure to be considered (e.g. cost estimation and integration of

[4] See Quirk (1976, p. 308) for a concise description of this kind of decision problem. A number of analyses have applied an economic value of information framework to the analysis of specific types of information or policy questions, including Nelson and Winter (1964) who explore the value of weather forecasting, Evans, et al. (1988) who address the value of home radon monitoring, and Hammit and Cave (1991), who explore the value of food safety research.

estimates into decision-making). Having done so, the procedure is judged on the basis of its ability to alter prior beliefs (about prices, costs, consumer demand) and in turn, alter a firm's decisions. Finally, the economic benefit of the changed decision is estimated.

It should also be emphasized that the value of information as discussed in this paper relates to the *private* value of information; that is, the information's value to a specific firm. As will be seen, better information can lead to decisions that are socially desirable. Our focus, though is on the value of information to a profit-motivated corporation.

3.2 Application of the Framework

To further motivate this framework, consider a hypothetical manufacturer that uses chemical A and several other inputs to produce a product for sale. Chemical A can be purchased for $50 per gallon. Unfortunately, the use of Chemical A creates a toxic, regulated by-product that must be disposed of at some cost. The chemical's contribution to the plant's overall disposal costs is not known with precision and, from an accounting standpoint, simply appears as a general facility overhead cost. In other words, the disposal cost is not assigned to the process or product in which is used. How would we use the framework to estimate the potential value of better environmental accounting?

<u>Define the accounting goal</u>

In this case, the reformed accounting procedure involves the calculation of a marginal disposal cost X associated with the use of Chemical A. This calculation will allow a more accurate estimate of Chemical A's true input cost ($50 + X is the true cost). Having calculated the true cost, an additional goal is to integrate that cost into the firm's planning and other optimizing, decision-making processes.

<u>Identify the costs of achieving the goal</u>

Calculation of disposal costs may involve a set of tasks. It may be necessary to calculate material flows (an engineering exercise) from the plant's production process so that wastes can be desegregated and tracked. These material flows will then have to be translated into disposal costs. This calculation can be complex. Consider the issues that arise if the waste is destined for landfill disposal. First, there will be marginal disposal costs associated with transport of the waste. Second, the waste's contribution to landfill costs must be calculated. If a third-party landfiller is to be used, costs will include the tipping fees. If the firm invests in a landfill dedicated to its own waste, it will be necessary to calculate the waste's contribution to fixed landfill costs, which can be substantial. This type of calculation may be complicated by the discounting issues associated with the construction of a long-lived landfill asset. In addition, contingent liability risks associated with landfilling may need to be calculated. This will be a function of technological, geological, chemical, and legal factors.[5]

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[5] For examples of methodologies used to predict contingent environmental liabilities see EPA (1996).

The costs of achieving the goal are a function of the disposal process itself, the nature of the waste, and the availability of existing data on costs (i.e., landfill fees). There will also be costs associated with the integration of the data into the firm's accounting and decision-making processes.

Assess the scope of alternative actions

We now turn to the potential benefits of having a more accurate estimate of Chemical A's true cost. As described above, this requires knowledge of the firm's ability to change its actions in response to better information. If the disposal cost X of Chemical A is revealed to be significant, how might the firm respond? This is a question that hinges primarily on the firm's technological options and the availability of substitute inputs. Substitutes can take a variety of forms. Most obviously, the firm might alter its production process by substituting some other chemical input for Chemical A. But substitutes can take a much wider variety of forms. Perhaps a more mechanical, or labor-intensive production process can be substituted. Perhaps the product can be redesigned altogether.

More precisely, the question to be addressed is whether there are substitutes available at less cost than the true cost of Chemical A. Substitutes that meet this requirement will not always be available. For instance, "retro-fitting" existing production facilities in order to employ substitutes is, as a rule, likely to be quite expensive. The availability of financially viable alternative actions may be higher at the design stage of a process or product's development.[6]

It should also be noted that technological issues are not the only factors than can constrain a firm's ability to pursue alternative actions. In some cases, environmental regulation itself may constrain a firm's ability to adjust its manufacturing processes. Innovative technologies are by definition untested and so may face a set of regulatory hurdles that, if nothing else, add to the costs of substitute production processes or product designs.

Another possibility is that the cost assessment of Chemical A will reveal economically desirable disposal options. For instance, if incineration is a technical and regulatory possibility, knowledge of landfill costs may steer the firm toward an alternative disposal technology. This underscores the need to examine a very wide range of alternative actions, not just those associated with input re-configuration. It also highlights the possibility that improved environmental accounting information need not lead to decisions that are better for the environment.

The availability of alternatives is clearly central to the question of whether or not the firm can gain from having better cost information. If there are no available substitutes

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[6] This claim is made with some caution. While it is clearly cheaper to optimize a product or process while still in the design phase, new products and processes can entail problems of their own. For instance, benefits (such as demand for a new product or avoided costs) may be uncertain, thus placing its financial viability in some question. This type of issue is explored in more detail in Section 5.

(substitutes at less cost than the original input), then the value of improved information will be small.

Determine whether prior beliefs are likely to be significantly altered

For new information to be valuable it must, of course, actually be *new* information. If new cost estimation or accounting procedures simply confirm existing beliefs, they have little likelihood of contributing to changes in decision-making, and thus little likelihood of adding value. Environmental accounting techniques will be most valuable when they correct beliefs that are biased or when they focus on issues subject to high degrees of uncertainty.

A focus in much of the environmental accounting literature is on the failure to quantify environmental benefits and costs. The concern is that when benefits and costs are unquantified they are not only uncertain, but will actively bias decision-making. Consider again the example of Chemical A. Being unquantified, the concern is that the disposal cost X is interpreted by the firm as a non-existent cost (i.e., X = 0). Since disposal costs are positive, this type of belief is almost certainly biased. As a result, managers and engineers under-estimate the cost of Chemical A and consequently over-utilize it in the manufacturing process. In general, it is probably safe to assume that non-quantified environmental benefits and costs are subject to these types of bias and thus good targets for improved accounting procedures.

However, it is important to note that beliefs need not be significantly biased simply because information is not quantified. For instance, the managers who decide how much Chemical A to use may understand that, because of disposal costs, its true costs are greater than $50. That is, there may be a *qualitative* understanding of the disposal cost X that influences the firm's decisions. While still uncertain, managers may estimate X to be something greater than zero, and thus closer to its true value. Analysis and quantification are likely to improve the quality of that estimate, but not as much as they would if we assume decision-makers treat it as a zero cost. Lack of quantification does not necessarily imply biased decision-making. Lack of quantification may simply indicate uncertainty and difficulties with the verification of data.

In some cases, there may be reasonable proxies for quantified benefits and costs. For example, a firm might possess relatively complete technical descriptions of material flows (inputs, intermediate products, emissions). These material quantities, while not explicitly translated into financial quantities, may provide rules of thumb that qualitatively inform decision-making and guard against severe errors in decision-making.

Finally, it is important to consider the difference between information that is collected by one unit of a firm and the transmission of that information to decision-makers who can act on it. For instance, environmental, health, and safety managers may possess a wealth of data that is useless unless communicated to and integrated by financial analysis, investment and production managers, and product design teams. Valuable reductions in bias and uncertainty are likely to result from the integration of a variety of types of environmental and non-environmental data analysis.

<u>Calculate the value of improved decisions</u>

Assuming that (1) new information will correct or improve the firm's prior beliefs and (2) the firm has the technical and regulatory flexibility to alter its decisions, we are ultimately concerned with the economic value of the changed decision. Given that the firm will "re-optimize" based on the new, better information, what is the value of that re-optimization?

Assume that Chemical A's cost was found to be grossly underestimated and that the firm was able to identify a substitute input B whose true cost was substantially lower. The information's value is the difference in true production costs using the different inputs. In general, this difference will be a function of the cost of substitutes and the production technology itself. If the firm responds to the new information by redesigning the product, the cost of redesign will reduce the value of the new, substitute action.

Note that, whatever the case, the value of re-optimization requires the calculation of a wide variety of baseline benefits and costs -- those associated with the actions taken without new information. Perhaps an even greater challenge is an understanding of the benefits and costs of substitute actions, since these are inherently more speculative.

4. A FORMAL ANALYSIS OF DECISION-MAKING

The framework presented above outlines a method by that can be applied to the evaluation of the benefits of improved environmental accounting. In this section we apply the framework more formally and to a specific form of decision-making. In this decision-making setting managers must make an optimizing decision based on incomplete information, information that could be improved at some cost by better accounting data or procedures. A simple but pervasive production decision is modeled--the choice and intensity of inputs to a production process--and the impact of improved input price information on the firm's decisions and profitability is calculated. The goal is to identify the factors that influence the value of information.

4.1 The Production Decision

The model explores a manager's decisions relating to the use of inputs in a production process. The firm uses capital K to produce a final output for sale, according to the production function $Q(K)$.[7] Also, the firm has a choice of capital inputs. For simplicity, assume two, perfectly substitutable forms of capital, K_1 and K_2 that can be used as inputs to the production function. The substitute forms of capital can be purchased at prices p_1 and p_2, respectively. There is a competitive market price p_m for the end-product.

The manager's optimization problem therefore involves two decisions. First, the choice of inputs, and second, the optimal level of production. This standard decision problem requires the manager to choose the least-cost input combination for a given level of production and set output so that the marginal revenue product equals the marginal cost of

[7] Output is assumed to be increasing in K at a decreasing rate.

production. If the manager believes that p_1 is less than p_2, and the inputs are perfect substitutes, they will use input K_1 and choose the level of capital that maximizes

$$\Pi = p_m Q(K) - p_1 K_1.$$

This yields the standard condition that

$$p_m \frac{\partial Q}{\partial K} = p_1 ,$$

or, the input's marginal contribution to revenue equals its marginal cost. This condition defines the optimal scale (input intensity) of production, given the manager's beliefs regarding the cost of inputs 1 and 2.

4.2 Two Types of Information Problem and Accounting Improvement

To explore the value of improved information we will consider an information problem associated with the price of input K_1. Assume that use of input 1 creates a costly by-product, due to the need for disposal, the possibility of regulatory penalties, etc. Let the per-unit cost of this by-product be denoted p_e. The accounting improvements we will describe relate to the manager's prior and subsequent beliefs regarding the costs of input 1's by-product. Consider the following two types of information problem -- and solution.

Case 1: *The manager believes that there is no environmental cost (that is,* $p_e = 0$*). The solution in this case is to correct the manager's inaccurate belief so that decisions can be based on* K_1*'s true, life-cycle cost,* $p_1 + p_e$*.*

Case 1 depicts a particularly extreme information problem. The manager not only mis-estimates the input's cost (the estimate is biased), but also fails to assign any subjective probability to the existence of positive environmental costs. In other words, the manager has complete confidence in an inaccurate estimate. This may be due to a particularly naive understanding of inputs and their relation to the full production life-cycle. It may also be due to inappropriate accounting procedures and incentives faced by the manager. For instance, the firm's managerial accounting procedures may assign all environmental costs to company overhead and not penalize managers for failing to minimize plant-specific environmental costs. If so, it may be rational for the manager to act as if input 1's price is p_1 rather than $p_1 + p_e$. The solution--the accounting improvement--is to correct the manager's biased estimate of environmental costs so that those costs influence the manager's optimizing decisions.

Case 2 depicts a different information problem, one where the manager is aware that the input has an environmental cost, but is uncertain of its magnitude.

Case 2: *The manager believes there is an environmental cost, but is unable to distinguish whether this cost is high* (p_{eh}) *or low* (p_{el}). *The problem is resolved when the true price is discovered or calculated.*

Case 2 assumes that the manager has a subjective, prior probability that the cost is either high or low. In the absence of information, the manager optimizes production given this uncertainty. Specifically, the manager makes the input choice and sets production levels given the *expected* price of input K_1.

Note that the manager in example 1 is optimizing given a biased estimate of input 1's price. In contrast, the manager in case 2 understands that there is a probability distribution over possible environmental costs and optimizes given an unbiased estimate of those costs.[8] As we will see, information has value in both cases.

4.3 The Derivation of Information's Value in Specific Production Contexts

We now consider, in turn, the value of improved accounting given the information problems described in cases 1 and 2 above. It is necessary to characterize the decisions made by managers both before and after the improvement in information.

The value of information in Case 1

Misperception of input 1's cost can lead to two types of error. First, it can lead to an inappropriate choice of input. This occurs whenever $p_2 < p_1 + p_e$. In such cases, input 2 is in fact the cheapest but the manager will employ input 1 (due to the misperception that $p_e = 0$ and the fact that $p_1 < p_2$). Second, an excessive level of production will be chosen if input 1 is utilized, since the firm underestimates K_1's cost.

Correcting the misperception allows for re-optimization based on the input's true cost. The value of this correction is calculated as follows. Assume that $p_2 < p_1 + p_e$, so that K_1 is the higher cost, and utilized, input. Let K^o denote the level of capital that satisfies

$$p_m \frac{\partial Q}{\partial K} = p_1 .$$

Thus, K^o is the input intensity chosen when the manager is misinformed. Let K^* denote the level of capital that satisfies

$$p_m \frac{\partial Q}{\partial K} = p_2 .$$

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8 It is purely for simplicity that we assume only two possible prices. In most decision-making settings there is a continuous probability distribution over a wide range of possible outcomes.

This is the optimal level of input intensity given the use of input 2, the low-cost input. Note that since $p_2 > p_1$, $K^* < K^o$.

Given accurate knowledge of input prices, the firm chooses input 2 and reduces its input intensity from K^o to K^*. This re-optimization, based on accurate knowledge of prices, is beneficial. The incremental benefit to the firm of basing its decisions on accurate information is equal to

$$K^* \cdot (p_1 + p_e - p_2) + \int_{K^*}^{K^o} \left[(p_1 + p_e) - p_m \frac{\partial Q}{\partial K} \right] dK$$

This expression describes production cost savings that arise from the firm's re-optimization. First, the firm switches to the truly low-cost input. This creates a savings of $(p_1 + p_e - p_2)$ per unit of capital employed. Second, the firm reduces its input intensity to the first-best level. The benefits of this reduction are depicted in the second term. In the absence of accurate input price information the firm over-utilizes capital, given the cost $(p_1 + p_e)$ and its marginal contribution to revenue. By construction, input utilization at levels greater than K^* yield marginal benefits less than p_2 (and thus marginal benefits less than $p_1 + p_e$). Optimization based on accurate information avoids those losses.

An accounting improvement yields value because the manager has the flexibility to adapt production in two ways, via the choice of input and via the intensity of input use. Misperception can lead to sub-optimal decision-making on both counts. Improved information creates value by allowing for re-optimization on both counts.

Note that an important source of value arises from the manager's ability to substitute input 2 for input 1 in the event that input 1 turns out to be the high-cost input. If there is no effective substitute for input 1, the value of improved price information is reduced, since input 1 must be used irrespective of its price. With no substitute the value of information is only reduced, however, it is not eliminated. The firm's ability to adjust the level of investment to reflect the input's price remains a source of flexibility and potential value.

<u>The value of information in Case 2</u>

Now turn to the value of improved information in Case 2. The information problem in case 2 is one of uncertainty. In it, the manager is aware that input 1 has environmental costs, but is uncertain as to the magnitude of those costs. Let ϕ denote the prior, subjective probability that the cost is high (p_{eh}), while $1 - \phi$ is the probability that the cost is low (p_{el}). Further assume that if the price is high, input 2 is the low-cost input ($p_1 + p_{eh} > p_2$), while if it is low, input 1 is the low-cost input ($p_1 + p_{el} < p_2$). What is the value to the manager of having this uncertainty resolved?

In the absence of information, a rational manager optimizes production given the expected price of input 1, which is equal to $p_1 + p_{ea}$, where $p_{ea} = [\phi p_{eh} + (1 - \phi) p_{el}]$. Note that by using the expected value, a manager is appropriately acknowledging the lack of certainty.

(It would clearly be worse to base decisions entirely on one of these prices, while ignoring the possibility that the other is the actual price.) Even so, basing decisions on certain knowledge of prices is preferred to reliance on uncertain, expected prices.

Assume, given the subjective probabilities, that $p_1 + p_{ea} < p_2$. If so, the firm produces with input 1. This also implies that the firm chooses the level of capital investment that satisfies

$$p_m \frac{\partial Q}{\partial K} = p_1 + p_{ea} \; .$$

Let K^U denote the solution. Thus, with imperfect information the firm's decisions are characterized by the use of input 1 and a capital intensity equal to K^U.

How would the firm's decisions change with the resolution of uncertainty? First consider the case where input 1's environmental costs are found to be high (p_{eh}). In this case, the firm will shift to the use of input 2. And since input 2's cost differs from the expected cost of input 1, the firm will adjust its level of capital investment accordingly. On the other hand, if input 1's environmental costs are found to be low (p_{el}), the firm continues to use input 1 because it is in fact the low-cost input. The level of the input will be adjusted upward, however, to reflect the now certain knowledge that its price is lower than was expected.

The expected value of information can be calculated as follows. With probability ϕ the firm expects to learn that it should shift production to input 2 and reduce its capital intensity. With probability $(1- \phi)$ the firm continues to use input 1 but increases the level of investment due to certain knowledge of its lower cost. The expected value of information is therefore the expected value of making these production changes given certain knowledge of input 1's price.

Let K^{C1} denote the profit-maximizing level of capital given certain knowledge that input 1 is the low-cost input. Let K^{C2} denote the corresponding capital level given that input 2 is known to be the low-cost input. The expected value of information is

$$\phi \left[(p_1 + p_{eh} - p_2) K^{C2} + \int_{K^{C2}}^{K^U} \left[(p_1 + p_{eh}) - p_m \frac{\partial Q}{\partial K} \right] dK \right] +$$

$$(1 - \phi) \int_{K^U}^{K^{C1}} \left[p_m \frac{\partial Q}{\partial K} (p_1 + p_{el}) \right] dK \; .$$

The first term in brackets, and lightly-shaded area in Figure 1, describes the benefit from re-optimization when input 1's environmental cost is found to be high (which occurs with probability ϕ). By construction, when input 1's cost is high, input 2 is the low-cost input. Re-optimization therefore leads to input substitution, which yields an incremental benefit of

($p_1 + p_{eh} - p_2$) per unit of capital employed. It also leads to a contraction in the overall level of capital investment. The contraction is beneficial because it avoids losses associated with the firm's prior under-estimation of capital's cost.

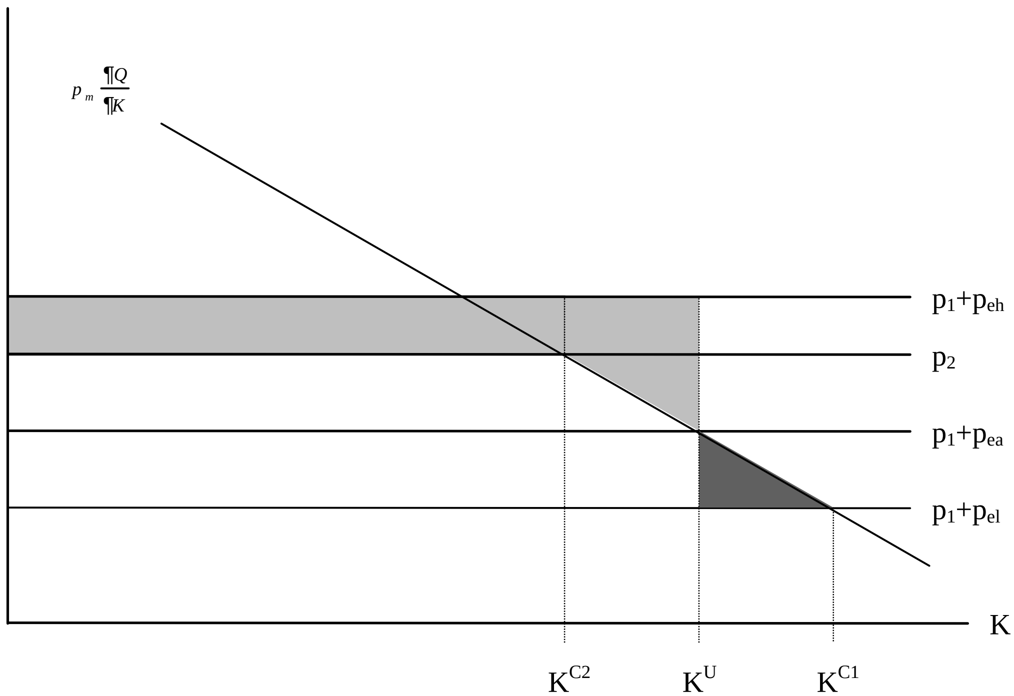

Figure 1

The second term represents the benefit derived when input 1's environmental cost is found to be low (the dark-shaded area in Figure 1, which occurs with probability 1- ϕ). When the environmental cost is found to be low, the firm expands output, since the now certain cost of capital is lower than its prior, expected level. This output expansion is beneficial because it allows the firm to capture benefits foregone due to its overestimate of capital's cost.

Note also that, as in case 1, the availability of substitutes increases the value of information. Even without the possibility of substitution to input 2, however, there would still be a value to resolving the uncertainty, due to the firm's ability to optimize the level of capital investment based on certain knowledge of capital's cost.

Finally, consider the way in which the value of information is dependent on the prior, subjective probability ϕ in case 2. Roughly speaking, intermediate values of ϕ denote greater uncertainty, and thus a higher value associated with improved information. As ϕ approaches either 0 or 1, the value of information approaches zero.[9] This corresponds to a situation in

[9] For instance, if the firm believes that $\phi \cdot 0$ it will make its input choice and choose a capital intensity consistent with the belief that the cost of capital is p_1+p_{el}. The cost of making these decisions is high if input 1 in fact costs $p_1 + p_{eh}$, but because $\phi \cdot 0$, the firm gives no weight to this possibility.

which the firm feels confident regarding its estimate of costs, and consequently believes that more information will simply confirm what it already knows. Of course, the firm may be wrong about this, if it is misinformed. But it underscores an important conclusion of any value of information analysis: namely, that information will be perceived as having value (and will therefore be pursued) only if uncertainty or bias is believed to exist.

Of course, formal economic analysis is only suggestive of the issues faced in a practical decision-making context. Clearly, managers in the real world must grapple with a far less stylized optimization problem than that presented above. Nevertheless, this kind of economic analysis helps identify the issues that any manager in the process of process optimization will face. What are the options available for process re-configuration, input choices, and levels of output? How does regulation affect the scope of those options?[10] And what is the value of re-optimization? Moreover, similar lessons can be applied in a variety of other decision-making contexts. Perhaps the most important context of all is the firm's capital budgeting decisions.

5. CAPITAL BUDGETING AND IMPROVED ENVIRONMENTAL ACCOUNTING

While accounting information is important to the optimization of production processes, procurement, service, and distribution, perhaps its most important application is in the firm's capital budgeting process. Capital budgeting decisions determine the scope of business activity, the design of facilities, and the development of new products. In many ways, a firm's capital budgeting process is its primary decision-making arena. It is the decision-making activity during which the widest variety of internal corporate expertise is brought to bear to evaluate costs, rewards, and risks. For this reason, it is desirable to explore the value of improved environmental accounting in the capital budgeting context.

5.1 Cash Flow Analysis

The capital budgeting process is largely concerned with the identification of the most desirable investment opportunities. This typically requires a set of relatively complex analyses designed to identify the characteristics of a new product, process or other business project.

For instance, the calculation of a project's net present value requires analysis of the timing and size of "cash flows" associated with the project. Cash flows include the initial cost of a project (the outlay) and its subsequent inflows (such as sales revenues). The first point to make about these calculations is that they are most frequently *estimated* costs and benefits, and thus are inescapably uncertain. Improved environmental cost accounting can improve the accuracy of these estimates by offering a more complete accounting of the cash flows and by providing estimates that exhibit less uncertainty. The value of improved accounting data is fairly obvious: the better the data, the more likely the firm is to pick investments with truly superior prospects. Analyses that detect and value environmental costs and benefits early

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[10] We return to this question in Section 6.

within the product and process investment and design phase are particularly valuable. First, because the ultimate profitability of the investment is a function of such costs. And second, because early identification of environmental consequences can identify opportunities for more environmentally desirable product and process re-configurations. Retro-fitting existing production processes is inherently much more costly. Design flexibility is at a maximum during the earliest phases of production.

Also, investment decisions are driven by perceptions of risk. All else equal, riskier projects are less desirable. (Another way of saying this is that riskier investments demand a higher return.) Environmental analysis at the initial investment stage can identify sources of risk and suggest opportunities for risk reduction.

Finally, detailed, project-specific environmental analysis complements incremental financial analysis. An inviolable principle of financial project evaluation is that new investments should be evaluated, not on the basis of their impact on average returns across a larger business, but on the specific costs and revenues generated by the project. Only the new, appropriately discounted, cash inflows and outflows created by the project are relevant. It is for this reason that the assignment of environmental costs to "overhead" is undesirable. The assignment of costs to such collective accounts discourages the identification of cash flows associated with specific projects. This makes the contribution of individual projects to the firm's profitability--the ultimate test for the desirability of an investment--more difficult to ascertain.

5.2 The Optimal Timing of Investment

When an investment has uncertain benefits and involves expenditure on irreversible investments, there is an incentive to avoid committing resources until the uncertainty is resolved. In financial parlance, there is an "option value" to delaying the investment decision. This is important concept in financial analysis because in such a situation the use of conventional investment rules, such as Net Present Value (NPV), can be an inappropriate test of an investment's desirability.[11] The investment manager's goal is not simply to select investments with the highest NPVs, but also to select the optimal *timing* of those investments (Pindyck, 1991). Information plays a critical role in those determinations. The timing of information affects the option value of delay, and thus the optimal timing of investment. Moreover, early access to improved information can be a significant source of value.

To motivate these ideas, consider a firm that is contemplating an investment in waste reduction technology. For the example assume a project with the following properties:

Cost of the investment:	$17 million
Annual benefit of the investment:	Either $5 million or $25 million

[11] Net present value is calculated by appropriately discounting all cash flows from a particular project. Generally speaking, a positive net present value calculation is indicative of a desirable investment opportunity.

Assume the investment's benefit arises due to the ability to achieve an environmental cost reduction. Note that the benefit is uncertain. Further assume that

Probability benefit is $5 million:	.8
Probability benefit is $25 million:	.2

For simplicity, assume the firm only produces over a 2-year period. There is a 10 percent interest rate.

Now consider two ways in which the uncertainty can be resolved. First, the firm can conduct an immediate accounting analysis, which will reveal the actual benefit, and do so prior to period 1 production. Second, the firm can delay the investment and complete its accounting analysis after period 1 and before period 2. It is assumed that the more immediate analysis is more expensive.

Cost of immediate analysis (and resolution of uncertainty):	$2 million
Cost of future analysis (resolution before period 2):	$1 million

The questions we wish to ask are, should the firm make the investment? When should it make the investment? And how quickly should it attempt to resolve the uncertainty regarding environmental cost reductions? In order to answer these questions a value of information analysis is necessary.

Table 1

Table 1 describes the cash flows associated with the firm's three principle options.

	Period 1		**Period 2**	
	Expected cost	Expected benefit	Expected cost	Expected benefit
1. Invest immediately w/out information	-17	5(.8) + 25(.2) = 9		5(.8) + 25(.2) = 9
2. Delay decision until period 2			-1 - 17(.2)	25(.2)
3. Resolve uncertainty immediately	-2 - 17(.2)	25(.2)		25(.2)

Option 1 is for the firm to invest immediately, without resolving the uncertainty. The cost of this option is $17 million investment cost. The expected benefit is $9 million per period.

Option 2 is for the firm to delay its decision and resolve the uncertainty prior to period 2. In this case, the only certain cost is the $1 million cost of the future analysis. If the analysis reveals that the benefits are high the firm proceeds with the investment in period 2. And the net benefit of the investment is $8 million ($25 - $17 million). Note, though, that the firm *ex ante* believes this will be the outcome only with probability .2. With probability .8 it expects to not make the investment at all.[12]

Option 3 is for the firm to resolve the uncertainty immediately at a cost of $2 million. In this case, it again believes there is a .2 probability that the analysis will reveal the investment to be high-benefit and thus worthy of pursuit. Because the analysis is conducted earlier, however, it would enjoy the $25 million benefit in both periods, should it turn out to be a high-benefit investment.

Now consider the value of these three alternatives. Assuming the firm makes the investment immediately, and without resolving the uncertainty, the project's net present value is

$$NPV_{\text{(Immediate investment, no information)}} = -17 + \left[(.8)5 + (.2)25\right] + \frac{\left[(.8)5 + (.2)25\right]}{1.1} = .18$$

The positive net present value would ordinarily suggest that the firm should move forward with the project. However, now consider the value of delaying the decision one period, and making the investment only if the environmental benefits are found to be high.

$$NPV_{\text{(Delay decision)}} = -\frac{1}{1.1} + (.2)\left[-17 + 25\right] = .55$$

Thus, the value of waiting and investing in information is greater than the value of investing immediately, without information. This is true because the information revealed after period 1 allows the firm to avoid the investment if the environmental benefits turn out to be small. Finally, consider the value of making the more costly, immediate investment in information.

$$NPV_{\text{(Resolve uncertainty immediately)}} = -2 + (.2)\left[-17 + 25\right] + (.2)\frac{25}{1.1} = 4.14$$

[12] Before the fact, and with probability .8, the firm expects the investment's benefits ($5 million) to be lower than its costs ($17 million). Therefore, *ex ante* there is a .8 probability the firm will choose to not make the investment in period 2.

Clearly, immediate resolution of the uncertainty is the highest-value strategy. Early resolution allows the firm to capture the benefits of investment over both periods, in the event that environmental benefits are found to be large.

The timing of investments is often a function of uncertainties faced by the firm -- uncertainties that can be resolved by investments in information. Improved information helps the firm seize opportunities when they are available and avoid costly mistakes when they are not. In general, improvements in accounting information will have a higher value when they bear upon investments with irreversible costs and uncertain costs or benefits. The example also suggests that the timing of investments in information is something that should be considered by managers. Depending on the investment being considered, the timely acquisition of information can be particularly valuable.

6. THE IDENTIFICATION OF PRIORITIES

The preceding analysis has shown how the value of information framework can help identify and evaluate the benefits of improved accounting. The value of information framework, combined with an understanding of accounting's role in corporate decision-making, highlights a set of consideration that should guide the search for environmental accounting priorities.

Detecting the Presence of Bias or Uncertainty

From a managerial perspective, high priority should be placed on identifying the most biased estimates of costs and benefits within the firm. One way to identify areas where bias is likely is to identify costs that are either not quantified or are quantified in an insufficiently detailed way. Lack of quantification may go hand in hand with bias because it is a signal of managers' failure to analyze a particular cost or benefit. Managers might also be polled to detect areas in which their perceptions of costs and benefits differ widely. Disparate estimates indicate higher degrees of uncertainty.

While lack of quantification is a potential signal of bias, it is important to note that managers may *qualitatively* weight unquantified costs in their decision-making. Qualitative weighting, while typically indicative of significant uncertainties, is an attempt by decision-makers to correct gross forms of bias that arise from an inability to quantify costs and benefits. Managerial decisions are rarely driven by cold numbers alone. This leaves substantial room for qualitative adjustments to otherwise unquantified costs or benefits.

Materials Accounting versus Financial Accounting

Materials accounting is an important example of a more qualitative response to unquantified cost information. Material quantification complements the qualitative weighting of environmental consequences by, for instance, providing data on quantities of emissions reduced by a particular project or process change. The financial value of these reductions may remain unknown. Nevertheless, the physical measure provides an approximate guide, however rough, to a financial value. In effect, materials data provides an imperfect measure of financial impacts, but is a measure that reduces bias and uncertainty.

Because materials accounting has inherently physical, and thus scientific and technical, content it may be viewed as a more credible index of environmental impact. The translation of physical emissions into a bottom-line financial impact--financial accounting--is much more speculative and therefore may be more likely to be disregarded by decision-makers.

The Credibility of Accounting Information and Procedures

For information to have a meaningful impact on firm decisions it must not only be based on sound analysis, but must also be viewed as credible by the managers who are to use it. This can be a formidable challenge when the accounting analysis involves complex analysis and relies on information that is not readily available--and thus not easily verifiable.

The credibility of an accounting analysis is also undermined to the extent that there is suspicion regarding the motives of the managers conducting the analysis. For this reason it is desirable to align the incentives of managers responsible for accounting analysis with the interests of the firm as a whole. This is by no means a simple task. Compensation that rewards short-term results is a classic example of a managerial incentive scheme that fails to appropriately align incentives.

The credibility of accounting information can be enhanced by improved information flow within the firm, so that data and methods can be evaluated by a diverse set of users. Retrospective audits of accounting data (and penalties for misrepresentation) can also be beneficial. Finally, information that can be supported by data sources external to the firm are likely to enhance the credibility, and therefore usefulness, of the information.

The Importance of "Non-environmental" Accounting

The decision-making models developed in section 4 derived the value of better information associated with the environmental costs of a single input. This is commonly viewed as the goal of environmental accounting -- better estimates of a process or product's environmental consequences. Note, however, that the value of information analysis required a variety of other types of information. This information included the prices of substitute inputs, knowledge of the rate at which the plant could turn capital into output, and the value of the product on the market.

This underscores an important point: improved environmental accounting is unlikely to have value unless it is appropriately integrated with "non-environmental" data. For instance, the value of information requires knowledge of baseline financial and environmental performance -- the costs and benefits of decisions made in the absence of the information. As was shown, the value of information arises from its ability to yield re-optimized (more profitable or less costly) production decisions. The value of re-optimization must clearly be calculated in reference to pre-existing production costs and estimates of savings arising from process re-engineering. Much of the information needed to evaluate existing production and the possibilities for re-optimization has nothing whatsoever to do with environmental costs and benefits.

It is also worth noting that many types of non-environmental accounting data are often incomplete and surprisingly imprecise. Thus, evidence of poor environmental accounting data and procedures may often go hand in hand with poor accounting techniques generally.

Accounting for Lifecycle Costs and Externalities

The principal goal of environmental accounting initiatives is the identification of decisions that will both enhance profitability and lead to environmental improvements. As argued in this analysis, it is the desire for enhanced profitability that will ultimately drive private-sector efforts toward improved environmental accounting. Clearly, the value of environmental improvements is closely related to the costs a firm bears if it fails to make those improvements.

Not all environmental costs are internalized by firms. For instance, life-cycle costs that arise throughout the chain of a product's manufacture, use, and disposal may not be internalized by a particular firm. In this type of case, life-cycle cost accounting will arise only if there are regulation- or market-driven incentives for firms to take life-cycle consequences into account. Regulatory attempts to promote voluntary accounting for external costs are likely to face formidable challenges, since there is little or no profit motive for acquiring that type of information.

It is also worth noting that some environmental accounting improvements may have the properties of a public good. That is, the improvements yield a benefit to a particular firm, but also yield significant benefit to other firms. If so, there is an inadequate private incentive to make the appropriate investment. In this type of case the social value of encouraging the investment may be significant relative to an individual firm's incentive. When this is the case, government-subsidized accounting information may be appropriate.

The Importance of Regulatory Flexibility

Information has value only if it leads to decisions different from those made in the absence of the information. As we have seen, the degree to which managers have the flexibility to adjust production processes is a key determinant of the value of information. The more flexibility, the greater the value. This has important implications for the design of environmental regulation.

Because regulation affects the range of technological options available to firms, it directly affects the value of environmental accounting information. Command and control regulation, the predominate form of environmental regulation in the U.S., often mandates specific control technologies. Moreover, technical constraints are often created by a reliance on standards that are applied to individual substances, rather than broader categories of effluent. Limits on the output of a single substance can significantly constrain the design (or redesign) of a production process.[13] By taking an end-of-pipe, single-media, and technology-forcing approach, command and control regulation leaves firms with relatively little reason to invest in improved environmental information. After all, if a firm is constrained in terms of the technologies and practices it can use to reduce pollution, what is the value of evaluating other options?

In contrast, flexible, performance-based regulation allows greater latitude for technological experimentation and longer time-horizons for compliance and thereby increases the value of information relating to those options.[14] Regulatory flexibility, by expanding the technological options open to firms, increases the value of information relating to those options. In the end, regulation that allows for a wide variety of innovative solutions is likely to be the best way to induce firms to invest in better environmental information and decision-making.

7. CONCLUSION

Economic and organizational analysis is central to the identification and critical evaluation of environmental accounting reforms. While better information is always desirable, it is also costly to acquire and implement. Thus, there is a real need for analysis that can identify priorities -- accounting improvements that are likely to yield the greatest private and environmental benefit. This paper has demonstrated the way in which a value of information analysis can facilitate the identification of those priorities.

Consider a hypothetical (and somewhat artificial) choice faced by a private sector manager or regulator seeking to promote environmental accounting reform: should effort be geared toward improved environmental liability estimation or improved materials accounting? Both efforts lead to more accurate estimation of production costs. In the case of liability estimation, the firm is better able to value the long-term legal costs of wastes associated with production. In the case of materials accounting, the firm physically measures input inflows, in-process inventories, and outputs (including wastes). These physical measurements in turn provide a foundation for the financial estimation of costs associated with the inputs and outputs of a given production process. Which effort is likely to have the greatest value?

Consider one way to approach this question, that uses a single element of the value of information framework described in this analysis: the likelihood that the new accounting method will correct pre-existing information biases. From a practical perspective, liability

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[13] Emission standards may not explicitly dictate a technology choice. However, they often carry an implicit incentive to employ a standard technology. This is because standards are usually developed based upon the emission characteristics of specific technologies. Firms can minimize their likelihood of being found in violation of standards by employing the technologies on which the standards were based. Innovative approaches run a higher risk of generating permit violations or triggering permitting delays.

[14] Instead of judging environmental compliance on the basis of specific technological inputs or narrowly-defined emissions standards, performance-based regulation relies on more holistic measures of a facility's environmental performance. For instance, compliance with aggregate limits (on a larger "bundle" of chemicals), rather than chemical-specific limits, is consistent with a performance-based approach. Flexibility should not be confused with a lack of regulatory stringency. Flexible permitting, at the aggregate level, can be very stringent while allowing firms to meet aggregate targets in the way they best see fit.

estimation requires analysis of a wide range of uncertainties including those due to chemistry, toxicity, migration, epidemiology, legal standards, and commercial relationships that will affect the future division of liabilities. Risk analysis will result in an identification of these factors -- which is desirable. However, the ability of improved risk analysis to correct bias or reduce uncertainty is more open to question. First, historical data regarding these risks is of dubious value since most environmental liability data relates to risks, technologies, and legal situations that firms are not likely to encounter in the future. For instance, a firm's expected future liability costs should probably not be estimated by looking at its past Superfund liability costs. Because of Superfund, firms dispose of wastes very differently than they did 20 and 30 years ago. Second, the multiplicity of uncertainties implies that the end-product of any risk assessment will itself be a highly uncertain estimate of costs. In other words, existing techniques are unlikely to result in low-variance estimates of liability risks. Third, given the visibility of environmental liability costs in the last decade, decision-makers are relatively unlikely to be naive regarding the potential scale of environmental liabilities.

Now consider the ability of materials accounting to correct biases or resolve uncertainties. This technique involves the identification of discrete production processes and their associated inputs and outputs; in-process inventory data including the path of each substance, the generation of "non-product outputs, including wastes and recycled material; and ultimately the identification of costs associated with each waste.[15] The experience of New Jersey with regulatory programs that use materials accounting (or material flow analysis) is instructive. New Jersey has experimented with a "facility-wide permitting program" that is linked to its pollution prevention initiatives and materials accounting process.[16] Analysis of a set of cases emerging from this program revealed a large number of emissions sources that had not been identified by pre-existing permitting programs (Rabe, 1997). In particular, levels of permitted releases were found to bear a poor relationship to actual releases revealed by the materials accounting process. Because this process reveals new categories of waste and provides specific information on volumes, it has a relatively greater likelihood of being able to correct decision-making biases.

This example is only meant to be suggestive. As the analysis has emphasized, the relative value of new forms of information is specific to a much wider range of factors. In fact, the analysis of information's benefits starts with the following truism: information need not be valuable simply because it corrects a bias, provides greater detail, or resolves an uncertainty. Several other preconditions must be satisfied for information to have value. Decision-makers must have the flexibility to change decisions based upon new information and the benefits of re-optimization must exceed the costs of the improved information. Understanding these conditions, and the way in which they relate to practical business decision-making, is a necessary first step if we are to understand the benefits of better

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[15] See Dorfman and Wise (1997) for a more detailed description of materials accounting techniques.

[16] For a more detailed discussion of the connection between New Jersey's pollution prevention law and its attempts at integrated, facility-specific permitting, see Rabe (1995).

information. Further research is necessary to identify the way in which improved environmental accounting can be tailored to fit the special needs of particular firms, industrial processes, and product markets.

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