CBO MEMORANDUM

TRADABLE DISCHARGE CREDITS:
POTENTIAL EFFECTS ON
PRODUCERS AND CONSUMERS
AND METHODS FOR ESTIMATING COSTS

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This memorandum identifies some of the costs to consumers and industry of a policy that would reduce discharges of toxic pollutants into water. It also discusses how to estimate the costs of the policy. Although the policy in question uses economic incentives to give firms flexibility in meeting the goals for reducing discharges, much of the discussion about estimating the costs would apply to other methods of restricting discharges of toxic pollutants.

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SUMMARY AND INTRODUCTION

In recent years, some environmental policymakers have supported the use of economic incentives to improve the environment. Incentive-based policies are appealing because they can improve the environment at a lower cost than more restrictive policy alternatives that are currently being used. These more restrictive policies include technology standards (in which the government prescribes the particular technology that firms must use to reduce pollution) and uniform discharge requirements (in which firms must achieve particular levels of discharge, regardless of their cost of doing so). Incentive-based policies can cost less because they allow firms not only to reduce their pollution in ways that are least costly to them but also to vary the amount of pollution discharged, depending on the firms' costs of reducing it. This flexibility enables firms to seek low-cost methods of reducing pollution, including the use of new technologies.

Incentive-based policies have already been adopted for reducing air pollution. For example, the 1990 amendments to the Clean Air Act incorporated an incentive-based approach for reducing the emission of sulfur dioxide, which causes acid rain. Similar approaches are now being discussed for improving water quality. One possibility is to use tradable discharge credits to reduce the discharge of toxic pollutants that are likely to accumulate in fish. Reducing these toxic pollutants is of particular concern because of the health consequences of eating contaminated fish.[1]

Under a policy of tradable credits, the government would set an overall goal for reducing the discharge of these toxic pollutants into surface waters. For example, the government might specify that firms covered by the policy must reduce the total discharge of these pollutants by 50 percent. Covered firms would have the option of reducing their discharges by more than 50 percent and selling their excess reductions, called discharge credits, to firms that reduced their discharges by less than 50 percent. Firms could reduce their discharges by less than 50 percent only if they found a sufficient number of discharge credits to buy (see Box 1). The policy thus assures that the overall goal of reducing pollution (50 percent in this example) is met even though individual firms may reduce their discharges by more or less than that amount. Appendix A discusses the potential economic advantages of a tradable discharge credit policy.

The costs of any policy that causes firms to reduce pollution include costs to industry (such as the additional costs of using less polluting inputs or treating wastewater and the costs of unemployed workers if firms close), costs to consumers (such as higher prices or changes in the types of goods

1. Environmental Protection Agency, *National Water Quality Inventory: 1990 Report to Congress*, EPA 503/9-92/006 (April 1992).

BOX 1.
POTENTIAL DESIGN FOR A TRADABLE
DISCHARGE CREDIT POLICY TO DECREASE THE
DISCHARGE OF BIOACCUMULATIVE TOXIC WATER POLLUTANTS

Key Elements

- The federal government would set a percentage goal (for example, 50 percent) for reducing the total amount of discharges of bioaccumulative pollutants by covered firms into surface waters in the United States. This requirement would be phased in, increasing until the ultimate goal is met.

- Covered firms could comply by reducing their discharges by the required amount or buying "excess discharge credits" from firms that decreased their discharges by more than the required amount.

- The baseline for each firm could be their discharges as reported to the Environmental Protection Agency's Toxic Release Inventory (TRI) for a given year.

- Firms would not be able to exceed their baseline discharges or the current requirements of the Clean Water Act. That is, they would not be able to buy enough discharge credits to violate effluent guidelines or criteria for water quality.

Coverage

- The policy would cover pollutants that are likely to bioaccumulate in fish. Two alternative measures of this tendency are the pollutant's bioconcentration factor (BCF, the amount expected to accumulate when the food chain is not exposed) or bioaccumulation factor (BAF, the amount expected to accumulate when the food chain is exposed). Discharge credits would be traded based on pounds of pollutants multiplied by either their BCF or their BAF. Pollutants might also be weighted by a measure of their toxicity to ensure that trades do not worsen national water quality.

- The policy could cover firms that are required to report to the TRI. An important design issue is whether to limit coverage to TRI-reporting firms that discharge pollutants directly into water bodies or also to cover TRI-reporting firms that discharge pollutants into municipal sewer systems. In either case, the policy would cover a wide range of industries.

Key Advantage

- The trading of discharge credits may allow the overall reduction goal to be met at a minimum cost.

Key Disadvantages

- The policy may not solve some current problems with toxic substances that are specific to the water body or pollutant.

- Enforcement efforts may be limited by the quality of TRI data.

that are available to them), and the government's cost of administering the policy. This memorandum discusses the costs to industry and consumers of a tradable discharge credit policy. It describes how producers and consumers may be affected, the methods used to estimate these costs, and the information needed to make the estimates.

Estimating the costs of a policy is not a simple task, particularly a policy like the tradable discharge credit, which allows firms flexibility in how they can respond, encourages the use of new technologies, affects a wide range of industries, and is carried out over several years. Cost estimates are most useful when they recognize the underlying uncertainties and when the limitations associated with them are clearly stated. Estimating the benefits of a policy and understanding their uncertainties and limitations are equally important, although this memorandum discusses only the issues associated with estimating costs. The benefits of reducing the discharge of toxic water pollutants could include lower health risks (from drinking or swimming in contaminated water or eating contaminated fish), improved wildlife habitat and other ecological benefits (such as improved conditions for plant life), and improved conditions for recreational activities (such as swimming, boating, and fishing).

EFFECTS OF THE POLICY ON INDUSTRY AND CONSUMERS

The policy of tradable discharge credits provides firms with a tremendous amount of flexibility in how they comply with the policy. They can reduce their discharges by:

- treating their wastewater,
- using alternative inputs (for example, less toxic substitutes),
- changing their production process (for example, using toxic materials more efficiently or recycling them),
- altering the characteristics of their product in ways that reduce the generation of toxic discharges (for example, making paper less white), or
- reducing their production levels.

Alternatively, they can continue to discharge the same quantities of pollutants (subject to existing environmental requirements) and purchase discharge credits from firms that have exceeded the reduction goal. Firms that are able to reduce their discharges at a low cost may find it in their best interest to exceed their reduction requirement and sell their excess discharge credits.

Production Costs Will Increase

If firms choose to comply with the policy by treating their wastewater, using alternative inputs, changing their production process, or purchasing discharge permits, their production costs will typically increase.[2] The firms will encounter increased labor expenses to carry out process changes, higher costs of materials, and the expense of purchasing equipment. In addition, firms that choose to comply by buying discharge credits will also have that expense. Finally, all firms will have some transactions costs, including the increased labor needed to interpret the policy and to file the necessary reports to verify compliance. Transactions costs for firms that exchange discharge credits will also include the expenses of finding a buyer or seller of discharge credits and obtaining government approval of the transaction.

As production costs increase, the difference between the firm's production costs and the price that it receives for the product becomes smaller, yielding a smaller profit. Because the per-unit profit decreases, the amount of the product that it is profitable for the firm to produce may also decrease. The firm's losses, therefore, may be from the lower profits on units that are sold and from decreased production.

A firm would suffer a smaller loss in profits if the price of the product increased as a result of the policy. In the extreme, if the price of the product increased by the amount of the firm's increase in production costs, then the firm's per-unit profits and level of production would remain the same.

Changes in Product Prices

The amount that the price of a product will increase as a result of the policy depends on:

2. Of course, there are exceptions: in searching for innovative ways to comply with the policy, firms may discover ways of improving their operations that actually save them money. For example, DuPont reportedly achieved a 50 percent decrease in the discharge of methyl ethyl keton (MEK) by virtually costless process changes that reduced annual operating costs by $120,000. In a more extreme example, Dow reportedly spent $250,000 on a process change that eliminated spent caustic wastewater and resulted in a savings of $2.4 million per year. (Note that the research and development costs associated with these changes are not reported.) See Mark H. Dorfman, Warren R. Muir, and Catherine G. Miller, *Environmental Dividends: Cutting More Chemical Wastes* (New York: INFORM, Inc., 1992), p. 56.

- the proportion of firms in the industry that are affected by the policy,
- the sensitivity of producers to price changes, and
- the sensitivity of consumers to price changes.

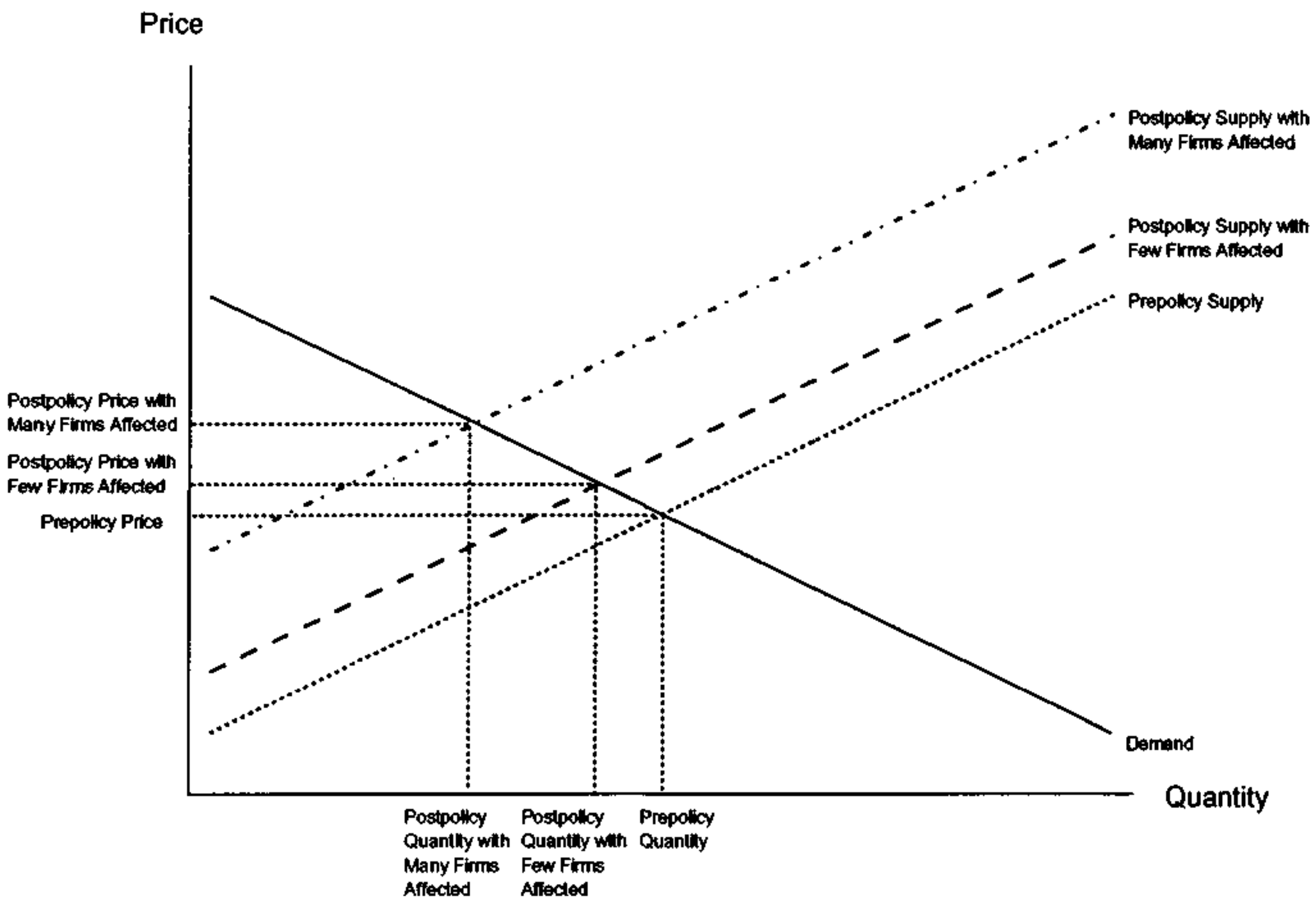
Proportion of Firms Affected. If the policy affects only a small proportion of the firms in the industry, the price of the product will increase by only a small amount, and the affected firms will absorb most of the cost. That would be the case if only a few firms in the industry discharged the covered toxic pollutants or if there were many foreign producers that would not be subject to the policy.

If the policy affects a large proportion of the firms in an industry, the price of the product is more likely to increase. More firms will be forced to demand higher prices for their product in order to stay in business and make a profit. That will tend to increase the price of the product and to offset the increase in costs incurred by any individual firm. Furthermore, because the policy affects a larger number of producers, less of the product will be made than if only a few firms in the industry are affected (see Figure 1). In addition, the total losses for the industry as a whole will be greater.

Sensitivity of Producers to Price Changes. The sensitivity of producers to changes in prices is an important factor in determining changes in production. In terms used by economists, if the quantity of the product that the industry can profitably supply is not sensitive to changes in prices, the supply curve is said to be "inelastic." In that case, very large changes in prices are necessary to bring about changes in production. If the quantity produced is very sensitive to changes in prices, then the supply curve is "elastic." In that case, small changes in price will result in changes in production.

The supply curve plots the relationship between the market price and the quantity of the product that can be profitably sold. Increasing costs within firms as production rises and variation in per-unit costs among firms cause the supply curve to slop upward--that is, more of the product can be offered only at higher prices. The more the incremental cost of production increases, the more steeply the supply curve slopes upward and the more inelastic it is.

Figure 1.
Changes in Prices and Quantities with Alternative Portions of Firms in the Industry Affected by a Policy



SOURCE: Congressional Budget Office

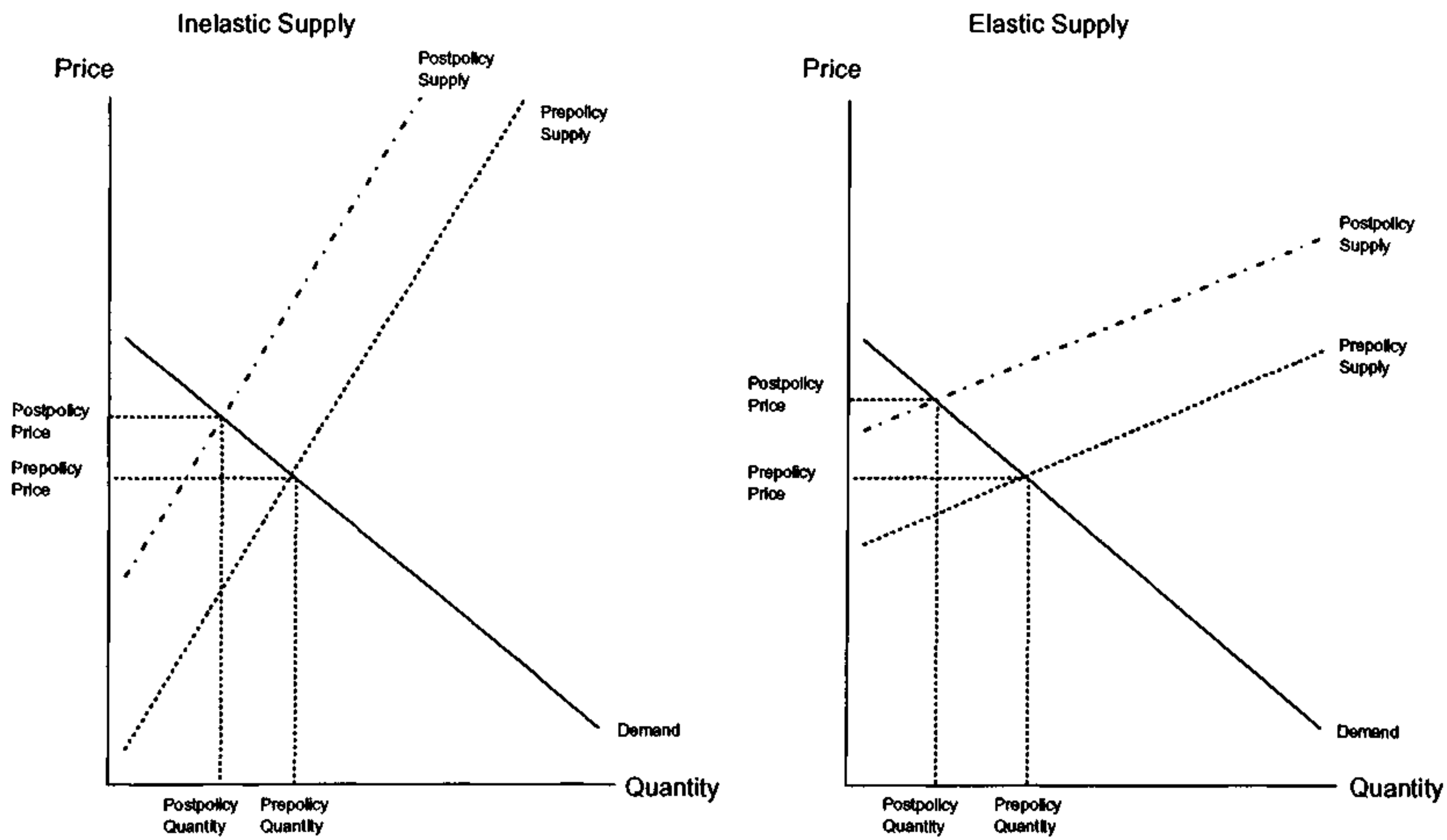
Costs may rise with increases in the quantity produced by an industry that relies on scarce or specialized factors of production. For example, production may require a specialized type of labor. To manufacture more of a product, the producer must attract more workers with the needed expertise, incurring higher wages and higher production costs. Some firms may have lower production costs than others because they have access to scarce or specialized factors of production such as special technical processes, exceptional management skills, a desirable location, a license to operate (for example, a permit to operate a hazardous waste incinerator), or access to inexpensive capital.

The availability of these specialized or scarce factors of production can lead to above-normal profits--profits that are higher than firms need to stay in business. Some firms--for example, one with a desirable location--receive the above-normal profits themselves. In other cases, these profits go to the owners of the specialized factors; for example, these profits may be paid in the form of patent royalties to the owner of a technology or as higher wages to specialized labor. These firms may absorb cost increases caused by a policy change either by reducing their own share of above-normal profits or by reducing the price that they pay to the owners of the specialized factors. Industries comprising these firms will exhibit an inelastic supply, and the reduction in the quantity produced as a result of the policy and the corresponding increase in the price of the product will be less than in industries with elastic supply curves (see Figure 2). The smaller reduction in output and smaller rise in price reduce the burden placed on consumers and the amount of job dislocation that results from the policy.

Sensitivity of Consumers to Price Changes. If consumers are very sensitive to changes in prices (that is, small changes in prices result in large changes in the quantity purchased), then the demand curve is said to be elastic. The demand curves of goods that are considered luxuries typically are more elastic than those of necessities. For example, consumers are more likely to buy fewer strawberries as a result of a price increase than they are to decrease the quantity of milk that they purchase. The availability of close substitutes also affects the sensitivity of the demand curve. If close substitutes are available, then the demand curve is likely to be elastic. For example, if the price of a particular brand of soap increases, consumers are likely to simply switch to another brand; but if farmers depend on a particular pesticide that has no close substitute, the price increase will have to be very large to cause them to decrease their use of it.

If the demand for a product is not sensitive to price changes, producers can pass the cost increases associated with a policy on to

Figure 2.
Policy-Induced Changes in Prices and Quantities for Industries with Inelastic and Elastic Supply Curves



SOURCE: Congressional Budget Office

consumers without causing them to buy less of the product (see Figure 3). The consumers of the product will bear most of the burden of the policy, and relatively few firms will close or cut back production. If the demand for the product is price-sensitive, however, the same policy tends to result in a smaller increase in price and a larger decrease in the amount purchased. Less of the policy's burden is passed on to consumers, more firms will close or cut back production, and more jobs will be lost.

Some Firms Will Be Better Off

The policy would impose different costs on individual firms. Costs vary among firms because the amount of pollution they discharge differs and because the abatement costs differ (as a result of factors such as location, size of waste stream, existing equipment, type of production process used, and so on). Firms that have a competitive advantage in abating pollution might benefit from the policy in two ways:

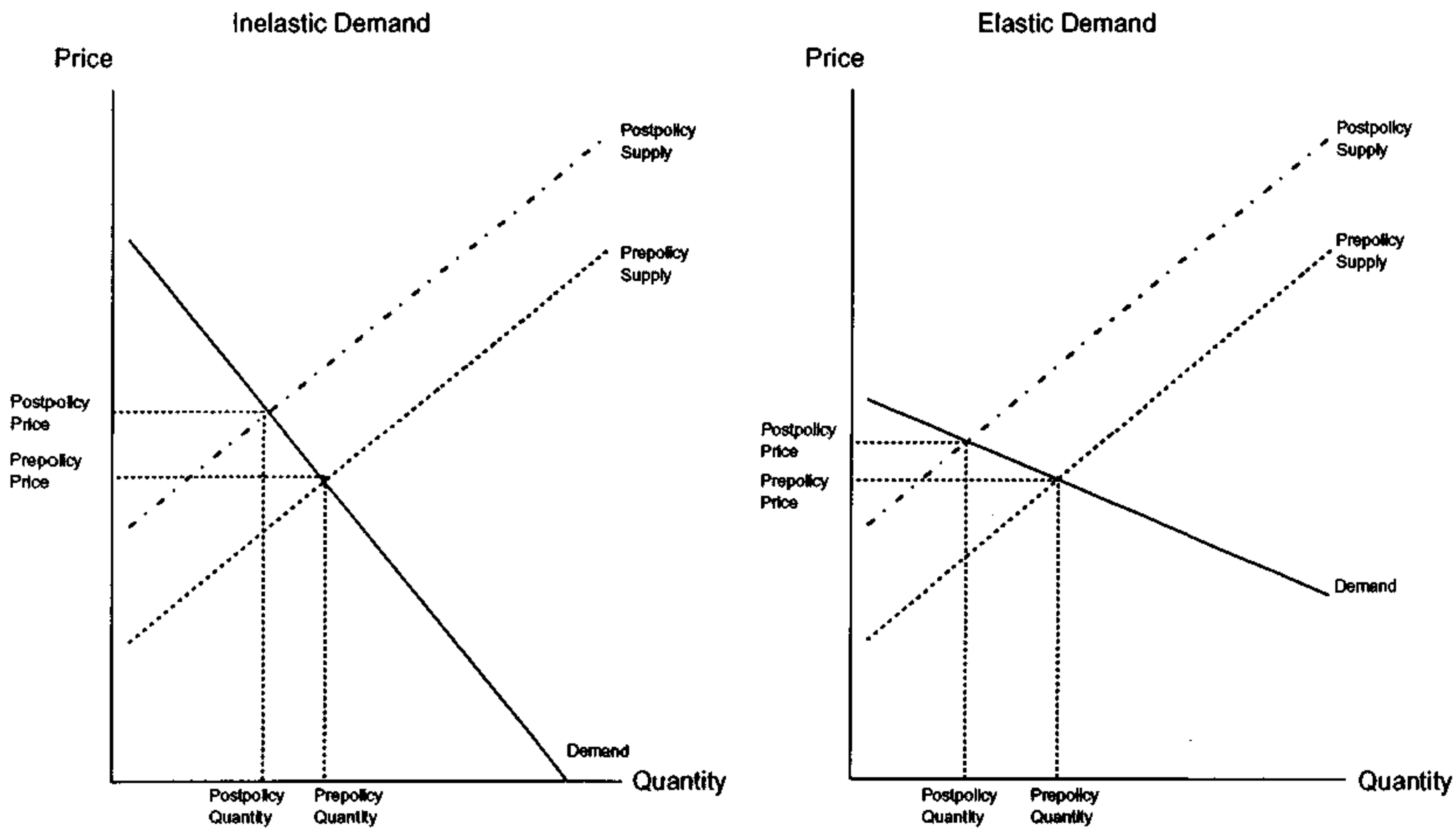
- o The increase in their cost of abatement may be less than the increase in the price of their product as a result of the policy.

- o They may be able to reduce their discharges by more than the required amount and to profit by selling their excess discharge credits to firms in their own industry or in other industries.

A firm whose costs of reducing discharges of pollutants (abatement costs) are less than the increase in the product price will be able to earn higher profits on each unit that it sells and will be better off as a result of the policy. Some firms may not incur any abatement costs because of the policy--for example, the policy does not cover firms that are not required to report to the Environmental Protection Agency's (EPA's) Toxic Release Inventory (such as those with fewer than 10 employees) or firms that do not discharge toxic pollutants into water. If the policy drives up the price of the final product, firms that do not have any abatement costs will be better off.

Firms whose abatement costs are lower than the price of discharge credits will be able to sell their excess credits at a profit. For example, if the price of discharge credits is $10 per pound of pollutant and a firm is able to abate for $2 per pound, its profit is $8 on each pound of pollutant that it abates above the required reduction.

Figure 3.
Policy-Induced Changes in Prices and Quantities for Products with Inelastic and Elastic Demand Curves



SOURCE: Congressional Budget Office

Other Responses of Firms

Some firms may have to shut down operations or substantially change their product as a result of this policy. Firms that have high abatement costs and low profit margins may shut down all or part of their operation, particularly if their products have close substitutes that are not adversely affected by the policy. These firms will not be able to pass the higher abatement costs on to consumers in the form of higher product prices. Firms that shut down rather than comply with the policy have the option of selling their excess discharge credits (50 percent of their baseline, in this example). In deciding whether to shut down, firms need to determine whether they would make more profit (or lose less money) by continuing to produce in the face of high compliance costs or by ceasing production and selling off their assets (including the excess discharge credits).

Some firms may reduce their discharges by altering the characteristics of their product (for example, by making their paper less white). Consumers may be willing to pay less for the altered product, though some may value the reduced environmental damage from the product enough to overlook the other changes. Alternatively, firms may have to sell their product in a different market--for example, it may be classified as an inferior grade. In that case, firms will expect to receive a lower price for their altered product. Furthermore, consumers of the original product will be worse off as a result of the policy. They may no longer be able to obtain some of the product characteristics that they desire, or they may have to pay more to obtain those characteristics because fewer firms would be producing products that have them. In contrast, consumers of the inferior-grade product may be better off because more firms will enter this market, thereby decreasing the price at which the inferior product is sold.

Indirect Effects

Estimates of the cost of the policy should include the effects on firms that the policy may indirectly affect, particularly if these indirect effects are expected to be large. Firms that may be indirectly hurt by the policy include firms that supply inputs to the affected industry. If affected firms switch production to an inferior product (as described above), firms that produce the inferior product will also be worse off because of the increased competition.

Firms that may indirectly benefit include firms that supply pollution abatement equipment or a substitute input that can decrease pollution (for example, a less toxic alternative). Producers of substitutes for the directly affected product also may be better off because the demand for the substitute may increase as the price of the affected product increases (glass container manufacturers may be better off, for example, if the policy increases the cost of producing plastic containers).

Transitional Costs

The changes in prices and quantities discussed above reflect the costs that producers and consumers are expected to bear after the industry has fully adjusted to the policy. There may also be some short-term adjustment costs, or transitional costs, such as temporarily higher prices on inputs that experience a transient shortage because of the policy. These inputs include pollution abatement equipment, labor specialized in pollution abatement, or less toxic inputs. Although these higher prices will make it more expensive for firms to comply with the policy in the short term, they will not affect the long-run cost of the policy. Firms may also incur costs to understand the policy and determine the best method of complying.

Transitional costs also include the short-term costs associated with facilities that close as a result of the policy. Capital equipment from these firms may be idled if it cannot be used productively elsewhere. Workers in firms that close or decrease production may be laid off.[3] Such dislocation causes personal hardship for these workers and higher outlays for the government for unemployment insurance and other social services. Although the personal costs of unemployment cannot be fully measured, the loss in income would persist until laid-off workers found other employment, and that could take time. Twenty-seven percent of workers who lost their jobs during the 1980s, for example, were unemployed one to three years later. Workers who eventually found new jobs were unemployed for 20 weeks on average.[4]

Noncompetitive Markets

The above discussion assumes that markets are competitive. In a competitive market, no firm is able to affect the price of its product; therefore, a firm's policy-induced cost increase would be offset by higher

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3. It is important to measure these costs carefully. If older, less efficient firms close, the actual cost is only the extent to which the policy hastens their closure.

4. Congressional Budget Office, *Displaced Workers: Trends in the 1980s and Implications for the Future* (February 1993).

prices only if a significant number of firms in that same industry also experienced cost increases.

But not all markets are competitive. In some cases, individual firms in an industry are able to affect the price of their product. First, if the number of firms in an industry is small enough, the actions of individual firms may affect product prices. Even if an industry comprises many firms, one firm may be so large that its actions affect product prices. Second, an individual producer may be able to differentiate its product and thus charge a higher price. For example, consumers may pay a premium for Levi jeans.

In these examples, individual firms have market power in that their actions may affect the price of the final product. Firms that have market power may be able to pass some of the cost of the policy on to consumers of their product even if the policy does not affect other firms in their industry. The amount of cost increases they are able to pass on would depend on the market share they control, how other firms in the industry respond to price increases, and the extent to which consumers would decrease their purchases as product prices rise (that is, the elasticity of demand).

GENERAL METHOD FOR ESTIMATING POLICY COSTS

To examine the effect of the policy on a particular industry, one must first predict how firms in that industry will respond to the policy--how their output, production costs, or product characteristics will change--and then total these responses to obtain the effect on the industry. Predicting how firms will respond to the policy is difficult, however; firms have a lot of flexibility in how they respond, and they may discover innovative methods of reducing pollution as the policy is phased in. The least-cost response is likely to vary even for firms within a given industry because of differences in firms' size, age, existing equipment, capital constraints, and so on. In addition, the least-cost response of a firm (say Firm A) to the policy (that is, its choice of whether to treat discharges, undertake source reduction, or purchase discharge credits) could be affected by other firms' responses in at least three ways.

- o The cost of reducing the discharges of other firms would affect the price of discharge credits, which may in turn affect Firm A's choice of whether to reduce discharges or buy discharge credits.

- o If many firms attempted to buy a similar type of abatement equipment or substitute input, the price of this equipment or input could rise and alter Firm A's least-cost response. This effect is referred to as a cost interdependency.[5]

- o If an abatement option of Firm A required clean water, the firm's ability to choose this option could be limited by the discharge practices of a firm upstream from it. This effect is referred to as a technical interdependency.[6]

Three Approaches for Estimating Costs

Given the flexibility in how firms may respond and the diversity of factors that could affect which responses are best for an individual firm, a great deal of care must be taken in estimating these responses. Three general approaches may be used: the survey approach, the engineering approach, and the combined approach.[7]

Under the **survey approach**, individual firms are asked to determine how they would respond to the policy and to estimate their costs. An advantage of this approach is that firms are likely to know the most about the circumstances that would affect their cost of alternative responses. This approach, however, has at least two disadvantages. First, investigating potential options and their costs could be very time-consuming. Firms may not be willing to commit the time and resources to this task until the policy is in place and they are forced to comply. Second, firms may have incentives to overestimate their cost of complying with the policy. They may feel that overestimating costs makes it less likely that the government would carry out the policy or may reduce the overall requirement to pollution reduction that is set.

The **engineering approach** provides an objective estimate of firms' responses and the corresponding costs. This method examines a set of possible responses and selects the one that minimizes compliance costs. Although this method is more objective than the survey approach, it has

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5. Henry M. Peskin and Eugene P. Seskin, "Introduction and Overview" in Henry M. Peskin and Eugene P. Seskin, eds., *Cost Benefit Analysis and Water Pollution Policy* (Washington, D.C.: Urban Institute, 1973), p. 13.

6. Ibid.

7. See Tom Tietenberg, *Environmental and Natural Resource Economics* (New York: Harper Collins Publishers, 1992), p. 85.

limitations. Engineering models may be able to account for some of the factors that affect an individual firm's options and costs (for example, volume of wastewater) but may not account for others (for example, existing equipment or proximity to suppliers of alternative inputs). Engineering models also fail to account for the creative responses that individual firms may devise.

The **combined approach** attempts to pool the strengths of the other two approaches and is likely to be the preferred approach. The survey approach may be used to learn how individual firms would respond under various circumstances. The engineering model may then be used to develop cost estimates for the potential responses, given the firms' individual circumstances. Information used in the combined approach may be enhanced by contacting firms that specialize in pollution abatement. These firms may provide insights into the methods that producers could use to reduce pollution and may provide estimates of the cost of these alternatives.

Using Sensitivity Analysis to Assess the Effects of Innovation

An important factor that none of these methods fully account for is the role of innovation in reducing the cost of complying with the policy. As firms seriously face the task of complying, they may discover new, lower-cost ways of reducing their discharge. In addition, as the government phases in the policy, new methods of reducing discharges may become available. One option for dealing with this source of uncertainty is to use sensitivity analysis, in which key parameters that may affect the cost estimate are varied over a reasonable range to provide an upper and lower estimate of cost. An examination of the role that innovation has played in the cost of achieving other environmental goals could provide insight into the amount by which innovation might reduce the costs of the tradable discharge credit policy.

Estimating the Price of Discharge Credits

The price of discharge credits is a key factor in determining the optimal response of each firm. Firms whose cost for reducing discharges was greater than the price of discharge credits would be better off buying credits than reducing discharges. Conversely, firms whose abatement cost was less than the price of credits would be better off decreasing discharges by more than the required amount and selling its excess discharge credits at a profit.

To determine which firms would buy discharge credits and which would sell them, firms are ranked according to the estimated cost of abatement. Beginning with the lowest-cost firm, the amount of abatement is totaled for all firms until the desired reduction in pollution is obtained (50 percent in this example). The cost of abatement for the firm at this cutoff point may be used as an estimate of the price of discharge credits. One can assume that firms with abatement costs above this cutoff point would buy discharge credits and that firms with lower abatement costs would sell their excess discharge credits.

Using General-Equilibrium Analysis

The effect of the policy on particular industries may be determined by totaling the compliance costs of the firms in that industry. As described above, the interrelationships of a firm's responses (that is, through the price of discharge credits, cost interdependencies, and technical interdependencies) must be accounted for. Because of these interrelationships, it is necessary to examine simultaneously the effect that the policy has on different firms in different markets. This approach is referred to as a general-equilibrium analysis.

As discussed earlier, the responsiveness of producers and consumers to changes in product prices is a key factor in determining how the policy affects them. The indirect effect of the policy on other industries depends on factors such as how well the less toxic inputs produced by those industries serve as a substitute for the more toxic inputs in the directly affected industry (called input substitution elasticities) or how well the products of those industries serve as a substitute for the product produced by the directly affected industries (called output substitution elasticities). The general-equilibrium analysis should include all markets that would be significantly affected by the policy.

INFORMATION AND DATA REQUIREMENTS

Making accurate estimates of the cost of the discharge credit trading policy requires a lot of information and data because of the large number of firms and industries affected, the flexibility of firms' responses, and the potential for innovation. Of particular importance is information on the factors that affect the costs of individual firms, such as the age of existing equipment, the volume of wastewater, the production process used and its potential for source reduction, the price and availability of less toxic substitute inputs, and the potential for changes in product characteristics. In addition, the initial prices and quantities in affected markets and the responsiveness of supply and demand to changes in prices are important for determining the changes in prices and quantities in those markets and how the policy affects producers and consumers. Finally, identifying substitution possibilities among final products and inputs and estimating the growth in demand for pollution abatement equipment are necessary for identifying indirectly affected markets.

Although still substantial, the information and data required to estimate the cost of the tradable discharge credit policy can be reduced by focusing on the key industries that the policy is likely to affect. If the policy affects a large number of firms in these industries, representative samples can be taken to estimate firms' costs. Data on characteristics of firms that can affect costs may be obtained from several sources, including EPA's Toxic Release Inventory, water pollution discharge permits issued under the National Pollution Discharge Elimination System, and surveys of firms in the affected industries or of consulting firms that specialize in pollution abatement. Survey information may be pooled with information provided by engineering models to estimate abatement costs.[8]

Determining the changes in prices and quantities resulting from the policy in directly and indirectly affected markets requires many elasticity estimates. Elasticities of supply and demand for some affected industries (for example, those that produce pesticides) may be found in the economic literature. In other cases, data may be available to estimate the elasticities directly.

Because of the large data requirements, the great amount of flexibility that firms have in complying with the policy, and the uncertainty associated with the type of technological change that the policy might motivate, it is crucial to use sensitivity analysis to identify the key factors that affect the cost estimates.

CONCLUSIONS

A tradable discharge credit policy has the potential to reduce water pollution at a lower cost than other alternatives because of the flexibility that it allows firms in choosing abatement levels and methods and because of the incentives that it provides for technological innovation. These same

8. The Computer Assisted Procedure for the Design and Evaluation of Wastewater Treatment Systems (CAPDET) model is one such model. It was developed by the U.S. Army Corps of Engineers and has been used by EPA in developing technology standards for industrial dischargers.

features, however, complicate the process of estimating the cost of the policy. The flexibility and incentives for innovation that the policy provides make it difficult for policymakers to predict how firms will respond and, therefore, to estimate costs. Combining survey information from affected firms and pollution abatement specialists with engineering models is likely to provide the best method of predicting a realistic range of firms' potential responses.

The tradable discharge credit policy described in this memorandum is likely to affect a large number of firms and a wide range of industries. Estimating the cost to each affected firm and industry would be difficult. One method for addressing this problem is to focus on the key industries that would be affected. The combined survey and engineering approach could be used for a sample of firms within those industries to provide estimates of firms' costs.

Because the effect of the policy on individual firms and industries depends on the resulting changes in other markets and on the price of discharge credits, it is necessary to look at the effect of the policy on multiple markets simultaneously--that is, to conduct a general-equilibrium analysis. Carrying out such an analysis requires much data. Besides information on how firms would respond to the policy, a general-equilibrium analysis requires information on the quantities sold in the affected markets, the prices at which they are sold, and the responsiveness of both producers and consumers to changes in prices. Some elasticity estimates are available or can be predicted from existing data. For others, a range of reasonable estimates may be used.

Because of the flexibility in firms' responses that the policy allows, the incentives for innovation that it provides, and the large amount of data that a general-equilibrium analysis requires, it is important to conduct sensitivity analysis on the results. Sensitivity analysis involves identifying the key parameters that influence the estimated cost of the policy and varying them over a reasonable range. This technique will help to ensure that policy decisions are not made based on "precise" cost estimates that are built on a shaky foundation.

APPENDIX A. ECONOMIC ADVANTAGES OF A TRADABLE DISCHARGE CREDIT POLICY

The tradable discharge credit policy described in this memorandum has the potential to reduce water pollution at significantly lower costs than technology standards or uniform discharge requirements because it:

- allows firms to reduce their pollution by different amounts depending on their cost of reduction,
- allows firms flexibility in how they reduce pollution, and
- encourages technological change by motivating firms to find new, low-cost methods for reducing pollution.

Variation in Firms' Abatement Efforts

Firms do not have identical costs of reducing pollution. The cost varies depending on a variety of factors including the types of pollutants a firm discharges, the volume of wastewater, the size of the firm, the abatement equipment already in place, the type of product the firm produces, and the type of inputs it uses. In addition, the per-unit cost of reducing pollution discharges generally increases with the quantity abated, that is, firms undertake low-cost abatement measures first and move on to progressively higher-cost measures.

The total cost of reducing pollution can be minimized by ensuring that the least expensive efforts are undertaken first. Firms will naturally seek to reduce pollution in the least-cost way. Some policies, however, such as a requirement that each firm reduce its discharges by some uniform percentage, might result in different firms having different costs of reduction. The total cost of meeting the overall goal to reduce pollution will be lower if the policy creates incentives for lower-cost firms to reduce pollution more and higher-cost firms to reduce pollution less.

Under a tradable discharge credit policy, firms have an economic incentive to allocate abatement activities among themselves in such a way that the incremental cost of abatement for each firm is equal at the desired level of pollution reduction. For example, if Firm A could reduce pollution at a relatively low cost and Firm B only at a high cost, then Firm B would have an incentive to buy discharge credits from Firm A. These discharge credits would require Firm A to increase its abatement efforts and would allow Firm B to forgo abatement. Firm B would want to buy discharge credits as long as the price of the credits was lower than its incremental cost of abatement. Firm A would be willing to increase its abatement efforts and sell its excess discharge credits as long as the price of credits was greater than its incremental cost of abatement. Firms A and B would therefore mutually benefit from this exchange, up to the point at which their incremental abatement costs were equal.

Flexibility in Methods Used to Reduce Pollution

Firms can reduce the amount they pollute by treating their discharges or by reducing the amount they generate. Technologies for treatment include activated carbon, biological treatment, and steam stripping. Source reduction activities decrease the amount of pollution produced in the first place rather than treat it once it is generated. These activities may include process changes, input substitutions, and product changes (see Box A-1). Incentive-based policies give firms the flexibility to seek the lowest-cost means of reducing pollution from among these options, whereas technology standards allow firms no such flexibility even though an alternative to the method prescribed in the technology standard may yield the same reduction in pollution at a significantly lower cost.

Encouraging Technological Change

Because the discharge trading policy sets reduction requirements for firms (50 percent in this example) but does not specify how they must achieve these reductions, it encourages firms to find ways of reducing their abatement costs--that is, it promotes technological change. Technological change includes two elements: innovation and diffusion. Innovation occurs when a firm discovers a new, low-cost method of reducing pollution. Innovations may occur in the area of wastewater treatment or source reduction. Diffusion occurs when one firm's innovation is transferred to other firms.

The tradable discharge credit policy allows firms to benefit from the internal use of an innovation in two ways. First, they can reduce the cost of meeting their own abatement requirement (the 50 percent reduction in discharges in this example). Second, if their innovation enables them to abate pollution at a lower cost than other firms, they can profit from selling discharge credits. In this example, they can exceed the 50 percent reduction requirement and sell their excess discharge credits at a profit.[1]

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1. Scott R. Milliman and Raymond Prince, "Firm Incentives to Promote Technological Change in Pollution Control," *Journal of Environmental Economics and Management*, vol. 17 (July 1989).

BOX A-1.
EXAMPLES OF SOURCE REDUCTION TECHNIQUES

Unless otherwise indicated, these examples are from Mark H. Dorfman, Warren R. Muir, and Catherine G. Miller, *Environmental Dividends: Cutting More Chemical Wastes* (New York: INFORM, Inc., 1992).

Process Changes. These are refinements or alterations in the chemical reactions, production techniques, plant operations, or equipment.[1]

Examples:

ICI Americas, Calif.: Removed the water from wastewater to reduce the discharge of trisodium phosphatedodecahydrate and allow the trisodium phosphatedodecahydrate obtained to be sold commercially. Implemented in 1987.

Fisher, N.J.: Operators were trained to ensure minimal solvent losses and decrease cross-contamination of segregated solvents.

Rhone-Poulenc, N.J.: Collected toulene in tank adjacent to operations unit, recovered it through distillation, and reused it. Implemented in 1990.

Input Substitutions. These involve using raw materials that create fewer toxic and hazardous wastes during the production process without necessarily changing the product itself. Included in this category are changes in chemicals used for operations outside the manufacturing process, such as cleaning and maintenance, pollution control, and corrosion inhibition.

Examples:

American Cyanamid, Ohio: Replaced a hazardous solvent, cellosolve acetate, with a nonhazardous solvent. Implemented in 1985.

Aristech, Ohio: Eliminated discharges of chromium by substituting a nonmetallic material for chromium used for corrosion resistance in cooling water. Implemented in 1989.

Product Changes. These involve redesigning the end product so its manufacture creates less toxic and hazardous waste.

Example:

A study of the pulp and paper industry revealed that dissolved solids and organic residuals could be cut by more than 80 percent by reducing the brightness of the final product while holding the other product characteristics constant.[2]

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1. *Environmental Dividends* distinguishes between process changes, operations changes, and equipment changes. In the examples provided, however, these distinctions were not clear. This paper therefore combines these three categories under the general heading of process changes.

2. Allen V. Kneese, "Costs of Water Quality Improvement, Transfer Functions and Public Policy," in Henry M. Peskin and Eugene P. Seskin, eds., *Cost Benefit Analysis and Water Pollution Policy* (Washington, D.C.: Urban Institute, 1973).

An innovating firm has an incentive to use its discovery to reduce its own abatement costs. However, whether the policy of tradable discharge credits encourages a firm to share this innovation with other firms depends on two factors:

- o Whether the firm is a buyer or seller of discharge credits, and
- o Whether the firm can patent the innovation.

Buyers of discharge credits generally have an incentive to promote the diffusion of an innovation. Since the innovation could lower the abatement cost of firms that are selling excess discharge credits, it would lower the price at which they are willing to sell them. Firms that buy discharge credits and promote the diffusion of a cost-lowering innovation may, in turn, benefit from the lower price of the credit. If the firm that discovered the innovation began to abate enough of its own pollution that it ceased to buy discharge credits, then this logic would no longer hold.

An innovating firm that sells discharge credits and is not able to patent the innovation has an incentive to prevent the diffusion of its innovation because diffusion diminishes the innovating firm's competitive advantage in abating pollution and decreases its ability to profit from the sale of discharge credits.[2] Conversely, a firm that is able to patent its innovation has an incentive to promote its diffusion even if it is a seller of discharge credits. The lost profits that the firm incurs because of its decreased sale of discharge credits after the diffusion of the innovation are likely to be more than offset by the royalties that it collects on its patent. The amount of the royalties that it collects would depend on the number of firms able to use the innovation and on the share of the innovation-induced cost savings that the innovator was able to capture through the patent.[3]

The cost of a flexible policy will be overestimated if the potential for technological change is not accounted for. Unfortunately, little information is available on the historical role that technological change has played in affecting the cost of environmental policies. In several cases, however, predictions have been seriously flawed by failure to account for technological change. One well-known example is the study *Limits to Growth*, which questioned the ability of natural resources to sustain

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2. Milliman and Prince, "Firm Incentives to Promote Technological Change in Pollution Control."

3. Ibid.

economic growth.[4] This study was seriously flawed because it failed to account for the role of substitution and technical progress in mitigating the effect of depleting resources on economic growth. As natural resources become more scarce, their prices will increase, which in turn will cause producers to substitute other inputs (such as capital and labor) for natural resources and consumers to substitute other goods for resource-intensive goods.[5]

Similarly, as the cost of discharging toxic pollutants into water rises, producers will substitute less polluting inputs in the manufacturing process and consumers will choose goods whose production involves less water pollution. The rising cost of water pollution will provide an economic incentive for firms to develop technologies that facilitate these types of input or product substitutions.

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4. Dennis Meadows and others, *The Limits to Growth* (New York: Universe Books, 1974).

5. Barry C. Field and Ernst R. Berndt, "An Introductory Review of Research on the Economics of Natural Resource Substitution," in Barry C. Field and Ernst R. Berndt, eds., *Modeling and Measuring Natural Resource Substitution* (Cambridge: MIT Press, 1981).