Working Paper Series

Working Paper No. 427

VALUING THE ENVIRONMENT AS INPUT

by

Gregory M. Ellis and Anthony C. Fisher

DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS

BERKELEY

CALIFORNIA AGRICULTURAL EXPERIMENT STATION

University of California

Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

Working Paper No. 427

VALUING THE ENVIRONMENT AS INPUT

by

Gregory M. Ellis and Anthony C. Fisher

Department of Agricultural and Resource Economics

University of California Berkeley

California Agricultural Experiment Station
Giannini Foundation of Agricultural Economics
October 1986

Valuing the Environment as Input[+]

Gregory M. Ellis and Anthony C. Fisher

Department of Agricultural and Resource Economics
University of California, Berkeley, California 94720, U.S.A.

Valuing the Environment as Input

The purpose of this paper is to suggest and then illustrate an approach to environmental valuation which we feel has considerable theoretical and practical appeal: valuation of the environment as an input to the production of a marketed good. This approach differs from the usual one in the economics literature in which demand is directly estimated for the environment as a final good. Some noneconomists have suggested using impacts of an environmental change on product revenues as a measure of the value of the change. We show how to use these kinds of product data in a way that is rooted (as estimates of revenue impacts are not) in the welfare theory generally accepted by economists.

Key Words: valuation, environment, input.

Valuing the Environment as Input

1. Introduction

The purpose of this paper is to suggest and then to illustrate an approach to environmental valuation which we feel has considerable theoretical and practical appeal. Management agencies, such as the Environmental Protection Agency, are often confronted with the problem of estimating the benefits of a proposed program, which in turn involves valuing a natural environment. Great strides have been made in this area in recent years as indicated in this journal by Loomis and Walsh (1986).

These authors, however, focus on valuation of the environment as a final good, i.e., a good that directly enters consumers' utility functions. In this category, for example, are the benefits provided by an improvement in air or water quality to on-site recreationists or to nearby homeowners. Much of the empirical work in environmental economics has, in fact, been directed toward determining the benefits of goods, such as outdoor recreation, by estimating the demand for these goods, often in ingenious ways as discussed by Loomis and Walsh. What we propose is to focus, instead, on the supply side by considering the environment as an input to the production of some marketed or marketable good--a supply of fresh water for drinking, perhaps, or a shellfish harvest. This approach has the advantage of relying primarily on production or cost data, which generally are easier to obtain (and for noneconomists perhaps easier to accept) than are the kinds of data needed to establish the demand for environmental goods.[1] Demand analysis will remain important, often as the only way of getting at some of the benefits discussed by Loomis and Walsh. But we shall demonstrate that, for other kinds of benefits, a supply-side analysis has some appeal.

In the next section we develop the welfare-theoretic basis of the analysis. In section 3 we work through an illustrative application involving the value of wetlands as an input to commercial fishing. In section 4 we indicate how the analysis would be modified by a more explicit treatment of the dynamics of the fishery (or other renewable resource).

2. The Welfare-Theoretic Basis of Environmental Resource Valuation

Because we shall be drawing on the wetlands application later on, let us set the discussion of value theory in the same framework. This will help us to visualize the concepts, and extension to other kinds of environmental systems should be fairly obvious.

An aquatic ecosystem, such as a wetland, functions as an input to production whenever changes in the characteristics of the system affect the costs of providing a good or service. For example, the number of wetland acres available as a habitat for fish may influence the cost of harvesting commercially valuable species. Another example is that the quality of water withdrawn from rivers and lakes for municipal water supplies determines the cost of subsequent water treatment. Wetlands reduce the cost of water treatment by removing or settling pollutants. This can be represented as a shift in a marginal cost or supply curve for fresh water along a given demand curve. An environmental improvement, such as provision of additional wetlands, would then involve a supply shift downward and to the right as in Figure 1 from S to S', where the shaded area between the old (S) and new (S') supply curves indicates the theoretically preferred measure of welfare gain, i.e., the change in combined consumer and producer surplus.[2]

This is probably a typical case but others are possible and, it turns out, relevant to the existing literature. One in particular is worth noting. Suppose the new cost, or supply, curve is simply the horizontal axis. In other words, creation of wetlands completely eliminates the need for human inputs, at least up to a point (represented by Q" in Figure 2). Then the welfare gain illustrated in the figure is the shaded area between the old and new supply curves up to the point (Q' on the figure) where demand equals the old supply and between demand and new supply thereafter (up to Q"). Note that this is less then the area between the two supply curves. Beyond Q', consumer willingness to pay for water is less than the old cost of treatment, so the latter is no longer relevant.

The same point is made more dramatically in Figure 3. There the old cost of treatment or supply curve lies everywhere above the demand curve. The benefit of the environmental improvement, represented as a shift in the supply curve to coincide with the horizontal axis, is then simply the area under the demand curve (up to Q"). The area between the two supply curves, which is just the area under the old curve, or the cost of providing treatment in the absence of the wetlands would overstate the benefit of having the wetlands for this purpose.

This is essentially the difficulty with the pioneering study of the value of estuarine wetlands by Gosselink et al. (1974). They claim that an acre of estuarine wetland provides benefits that would cost $2,500 per year if produced by man-made treatment plants. As Shabman and Batie (1977) have noted, Gosselink et al. not only failed to test whether the good in question--clean water--would be demanded, they did not show that construction and operation of treatment plants represents the least-cost alternative, the true S' in

Figure 1. Indeed, Park and Batie (1979) argue that recent evidence suggests that adjustments in agricultural practices, such as restriction on the application of fertilizers that run off into estuarine waters, may be a less-costly alternative to the construction of treatment plants. This criticism of the deservedly influential work of Gosselink et al. is not to suggest that waste assimilation is not an important service provided by wetlands; however, care must be taken when determining how people value that service.

Now let us consider the commercial-harvest example. A substantial amount of the previous empirical work has sought to value the environment as input for this purpose in ways not fully consistent with the deceptively simple approach discussed thus far and summarized in Figure 1. The estimates tend to be based on measures of revenue or of changes in revenue. As indicators of change in social welfare, revenue figures exhibit at least two problems. First, they do not reflect the opportunity cost of producing goods and services. Second, demand for many fish and shellfish species is relatively price inelastic (Bell, 1970), so an increase in production due to an environmental improvement results in a decrease in total revenue implying incorrectly that the improvement does not lead to a welfare gain. About the best that can be said for the revenue calculations (with or without price effects) is that they are not relevant to the determination of a change in combined consumer and producer surplus--the preferred welfare measure.

A Council on Environmental Quality (1970) study illustrates this difficulty. The study reports that, due to the practice of ocean dumping, one-fifth of the U. S. shellfish beds are contaminated and closed. Assuming that the closed beds would be as productive as their open counterparts, the study concludes that an improvement in water quality would result in a

25 percent increase in quantity of shellfish produced and a subsequent 25 percent increase in total revenues. The increase in total revenues is claimed as the gain to society of cleaning up the shellfish beds. However, as long as demand is not perfectly elastic, an additional 25 percent in the amount of shellfish supplied to the market could be sold only if the price of shellfish fell. The estimate by the Council of an additional $63 million in shellfish revenues (the additional 25 percent) is for this reason an overstatement. But, in any case, the revenue figures do not reflect costs or willingness to pay for nonmarginal units and, hence, are not adequate measures of welfare.

An important question to address in valuing commercial fishing benefits is: What is the contribution of the ecosystem to the production process? It is a question some studies have failed to address. For example, Gosselink et al., in assessing the value of wetlands as a fish nursery, divide the annual dockside value of fish products landed by the total number of wetland acres to arrive at a value per acre in production of fish. However, imputing all of the revenue from commercial fishing to wetland acreage ignores the contribution of other fishing inputs such as labor and capital.

A more recent study by Lynne et al. (1981) suggests that it may be possible to isolate the contribution of environmental inputs to production. They develop a bioeconomic model in which human effort and wetlands are distinct inputs in the production of blue crab off the Florida Gulf Coast. The population of blue crabs is assumed to be a function of the quantity of local wetland acres. Since the successful harvesting of the crabs is modeled to be dependent on their population level, wetlands, which act to define the carrying capacity for blue crabs, appear as an input in the production function. The reduced-form production function is estimated according to the ordinary least-squares criterion; and, using the appropriate estimated coefficients, a marginal product for an acre of wetlands is calculated. Finally, the value of the marginal product for an acre is computed using current dockside prices.

The Lynne et al. study is laudable for valuing both wetland acreage and human input in the production of blue crabs. However, the analysis is not carried through to obtain estimates of consumer and producer surplus associated with specified increases in wetland acreage. This is the subject of the application in the next section.

3. The Value of Wetlands in Shellfish Production: An Illustrative Application

In the spirit of Lynne et al., consider the optimization problem faced by a pricetaking firm or industry where price is P and the unit cost of the human effort input is W:

$$\max_{X_1} P\,F(X_1, \bar{X}_2) - W\,X_1. \qquad (1)$$

The production process is posited to be a function, $F(\cdot)$, of two inputs: one (X_1) that captures the efforts of man to harvest shellfish and another ($\bar{X}_2$) that represents the contribution of an ecosystem variable such as wetland acreage. The bar over X_2 indicates that, for the time being, the acreage is fixed. Although we, like Lynne et at., model human effort as a single input (in this case the number of traps set), one may prefer to model explicitly the use of several inputs so that substitution among them can be studied.

We assume that the production of blue crabs can be represented as a Cobb-Douglas process. Although the Cobb-Douglas form is no doubt a simplification of the true production process (and probably is a poor approximation to reality for extreme values of either input), we use it here because our main purpose is to demonstrate the procedure for calculating changes in combined consumer and producer surplus. Therefore, substituting for the production function in (1) the Cobb-Douglas form and noting that cost minimization is the dual problem to profit maximization, the optimization problem can be rewritten as

$$\min_{X_1,\lambda} \mathcal{L} = W\, X_1 + \lambda(Q - A\, X_1^a\, \bar{X}_2^b) \tag{2}$$

where λ is the Lagrange multiplier; Q is output; and A, a, and b are parameters. Differentiating the Lagrangean with respect to the effort variable and the Lagrange multiplier yields

$$\frac{\partial \mathcal{L}}{\partial X_1} = W - \lambda\, A\, \bar{X}_2^b\, a\, X_1^{a-1} = 0 \tag{3}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = Q - A\, X_1^a\, \bar{X}_2^b = 0. \tag{4}$$

Since the production function is characterized by only one decision variable, X_1, (4) is the only equation needed to solve for the cost function, $C(\cdot)$.

$$X_1 = \left[\frac{Q}{A\ \bar{X}_2^b}\right]^{1/a} \tag{5}$$

$$C(W, Q, \bar{X}_2) = W\ A^{-1/a}\ \bar{X}_2^{\ b/a}\ Q^{1/a}. \tag{6}$$

Differentiating the cost function with respect to output generates the marginal cost expression,

$$\frac{\partial C}{\partial Q} = \frac{W}{a}\ A^{-1/a}\ \bar{X}_2^{\ -b/a} Q^{\ (1-a)/a}. \tag{7}$$

Presumably, the blue crab industry also faces a demand curve for its product. A simple constant elasticity demand function is given in (8), and the corresponding inverse demand function is given in (9):

$$Q = KP^{-m} \tag{8}$$

$$P = K^{1/m}\ Q^{-1/m} \tag{9}$$

where K is a parameter and m is the (constant) elasticity. Profit-maximizing firms will equate price and marginal cost so that the equilibrium level of blue crabs sold is given by

$$Q = \left[\frac{a}{W}\ K^{1/m}\ A^{1/a}\ \bar{X}_2^{b/a}\right]^{ma/[m+(1-m)a]}. \tag{10}$$

The result in (10) holds for all relevant values of wetland acreage, X_2, available for the biological promotion of the blue crab population. Therefore, we first compute the equilibrium output associated with various levels of wetland acreage and then the equilibrium price corresponding to the output from equation (9).

We proceed to calibrate the parameters of the model in order to construct an example which is reasonably compatible with the price, input, and output data used by Lynne et al. We also incorporate their econometric finding that the marginal product of an acre of wetlands is roughly 2-1/2 pounds of blue crab (annually). Although the demand for shellfish has been found to be relatively price inelastic (as we noted earlier), we assume in this case a high elasticity since the Gulf Coast fishery is presumably not the sole source of blue crab in the market. Welfare gains associated with an increase in wetland habitat (remember that we are considering only gains associated with the blue crab) are calculated as the change in consumer and producer surplus. These measures are presented in Table 1. For example, for a demand elasticity of -2.00, the net gain associated with an increase from 25,000 acres to 100,000 acres is $192,658. Successive increments in acreage add less to estimated benefits due to diminishing returns to the wetland input. The results of a sensitivity analysis, in which different elasticities (ranging all the way from -.25 to -3.45) are used to calibrate the model, indicate that (in this example) the estimates of welfare gain are reasonably robust.

The purpose of this exercise has been to demonstrate that a theoretically correct measure of welfare can be constructed and calculated on the basis of empirical information about the impact on product supply (given demand) of a change in ecosystem characteristics (here the number of wetland acres). Of course, this has been a hypothetical exercise; in an actual case study, one would need to estimate the product demand and cost functions in question. Moreover, if the estimated demand function includes an income variable, simple Marshallian consumer surplus is no longer the appropriate welfare measure. Fortunately, for a variety of functional forms for the demand function, exact surplus measures are known and available [see, for example, Hausman (1981) and Hanemann (1981)].

4. Dynamics of Resource Recovery and Welfare Evaluation

In the preceding sections, we presented a method for evaluating the gain in welfare associated with a change in an environmental input and the resultant bioeconomic steady state. The comparison of steady states before and after an environmental improvement is of considerable intrinsic interest; however, given the intertemporal nature of growth and depletion of natural resource stocks, more sophisticated dynamic analysis may be warranted. Here, we briefly set out the framework.

A welfare analysis, which recognizes the dynamic nature of resource problems, should compare the time path of the bioeconomic system governed by an initial value of an environmental input, $\overline{X}_2$, with the path corresponding to a new value of the input, $\overline{X}_2'$. For example, the intertemporal change in a stock of fish or shellfish may be modeled as a differential (or difference) equation such as

$$\dot{R} = G(R, \overline{X}_2) - H(X_1, R) \tag{11}$$

where R is the resource stock, $G(\cdot)$ is a growth function, $H(\cdot)$ is the amount of the resource harvested, and X_1 and X_2 are defined as before. In bioeconomic equilibrium, $\dot{R} = 0$ or

$$H(X_1, R^*) = G(R^*, \overline{X}_2). \tag{12}$$

Equation (12) implicitly defines a steady-state production function (of X_1 and $\bar{X}_2$) such as the one employed in our steady-state analysis of the previous section.

The intertemporal profit-maximization problem facing a firm or industry is

$$\max_{X_1} \int_0^{\infty} \{PH(X_1, R) - WX_1\} e^{-rt} dt \qquad (13)$$

subject to (11) and an initial resource stock condition. As before, P is price, W is the per unit cost of X_1, and r is a time discount rate. Optimal control methods may be used to ascertain the intertemporal harvest associated with various values of the environmental input $\bar{X}_2$. Just as in the steady-state analysis of the previous section, once the time path of output is known, the demand equation may be used to calculate the present discounted value of consumer and producer surplus generated by the bioeconomic system with and without the change in the environmental input. The change in welfare may then be expressed as

$$\int_0^{\infty} \{CS(\bar{X}_2') + PS(\bar{X}_2')\} e^{-rt} dt - \int_0^{\infty} \{CS(\bar{X}_2) + PS(\bar{X}_2)\} e^{-rt} dt \qquad (14)$$

where CS(•) and PS(•) are consumer and producer surplus.

5. Concluding Remarks

We have proposed a way of valuing the environment, namely, valuing it as an input to production of marketed goods, that differs from the usual approach in the (environmental economics) literature of seeking to estimate directly the demand for the environment as a final good. Of course, we are not the first to suggest that value be imputed to the environment in this way. Noneconomists, in particular, have pointed to impacts of environmental changes on revenues from production of products such as fish and timber. What we have done is to propose and illustrate with a quantitative application a way to use the kinds of tangible product cost and demand data that may be congenial to noneconomists yet, at the same time, is firmly rooted (as estimates of revenue impacts are not) in the welfare theory accepted by most economists.

Footnotes

[+]This work was supported by a cooperative agreement with the U. S. Environmental Protection Agency and a grant from the Hewlett Foundation.

[1]In addition, we need data on demand for the marketed good whose supply is affected by a change in the environment; but, again, these data are generally available and not controversial in their interpretation.

[2]For a rigorous justification of the use of the change in consumer and producer surplus to measure welfare effects, see Just *et al*. (1982).

References

Bell, F. W. (1970). *The Future of the World's Fishery Resources: Forecasts of Demand, Supply, and Prices to the Year 2000 with a Discussion of Implications for Public Policy*. No. 65-1. U. S. National Marine Fisheries Service.

Council on Environmental Quality (1970). *Ocean Dumping: A National Policy*. Washington, D. C.: U. S. Government Printing Office.

Gosselink, J. G., Odum, E. P. and Pope, R. M. (1974). *The Value of the Tidal Marsh*. Center for Wetland Resources, No. LSU-SG-74-03. Louisiana State University.

Hausman, J. A. (1981). Exact Consumer's Surplus and Deadweight Loss. *Amer. econ. Rev*. 71, 662-676.

Hanemann, W. M. (1981). Some Further Results on Exact Consumer's Surplus. Department of Agricultural and Resource Economics, Working Paper No. 190, Berkeley: University of California.

Just, R. E., Hueth, D. L. and Schmitz, A. (1982). *Applied Welfare Economics and Public Policy*. Englewood Cliffs, N. J.: Prentice-Hall, Inc.

Loomis, J. B. and Walsh, R. G. (1986). Assessing Wildlife and Environmental Values in Cost-Benefit Analysis: State of the Art. *J. environ. Mgmt*. 22, 125-131.

Lynne, G. D., Conroy, P. and Prochaska, F. J. (1981). Economic Valuation of Marsh Areas for Marine Production Processes. *J. environ. Econ. and Mgmt*. 8, 175-186.

Park, W. M. and Batie, S. S. (1979). Methodological Issues Associated with Estimation of Economic Value of Coastal Wetlands in Improving Water Quality. No. VPI-SG-79-09. Blacksburg, Va.: Virginia Polytechnic Institute and State University.

Shabman, L. A. and Batie, S. S. (1977). Estimating the Economic Value of Natural Coastal Wetlands: A Cautionary Note. Costal zone Mgmt. 4, 231-247.

TABLE 1. Welfare gain associated with an increase in wetland acreage from an initial base of 25,000 acres

Elasticity (m)	Wetland acreage ($\overline{X}_2$)	Number of traps (X_1)	Change in combined consumer and producer surplus
2.00	100,000	29,575	192,658
2.00	200,000	30,986	295,290
2.00	300,000	31,842	358,843
2.00	400,000	32,464	404,139
2.00	500,000	33,000	437,688

Legends for Figures

Figure 1. Change in surplus from a shift in product cost curves.

Figure 2. Welfare gain when need for human input is eliminated by environmental improvement.

Figure 3. Welfare gain when product demand curve lies between old and new supply curves.

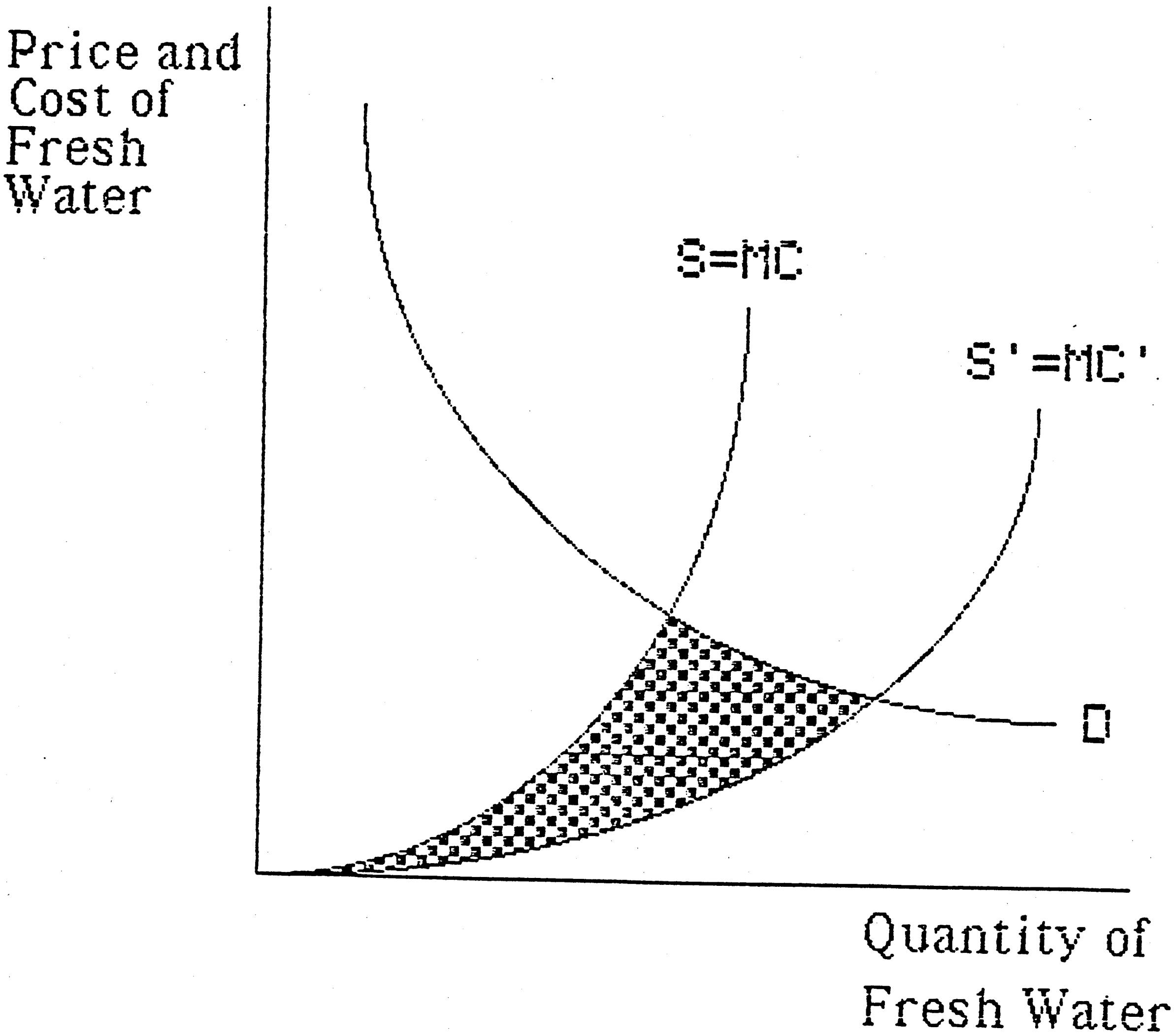

FIGURE 1. The Change in Surplus from a Shift in Product Cost Curves

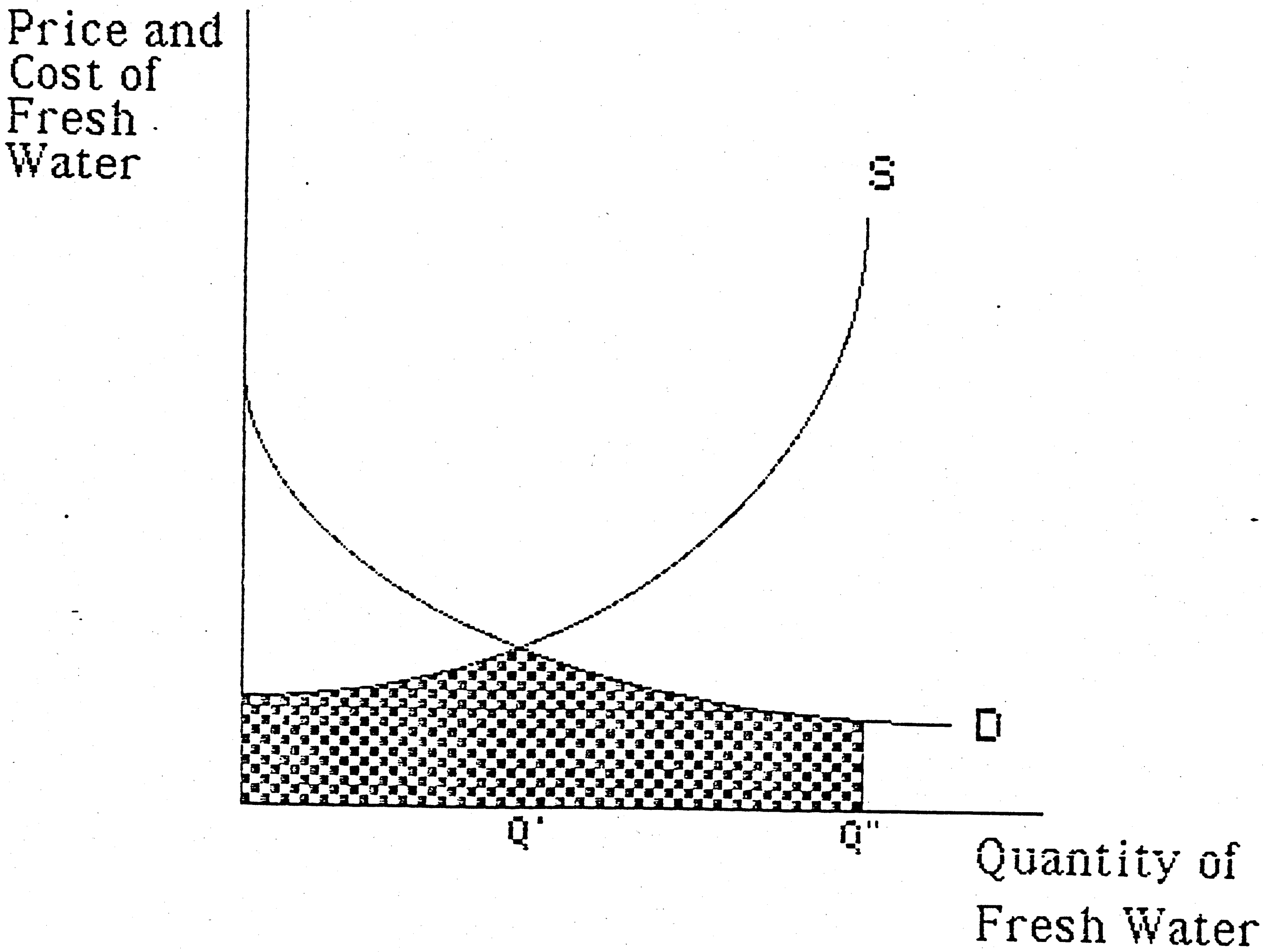

FIGURE 2. Welfare Gain when Need for Human Input is Eliminated by Environmental Improvement

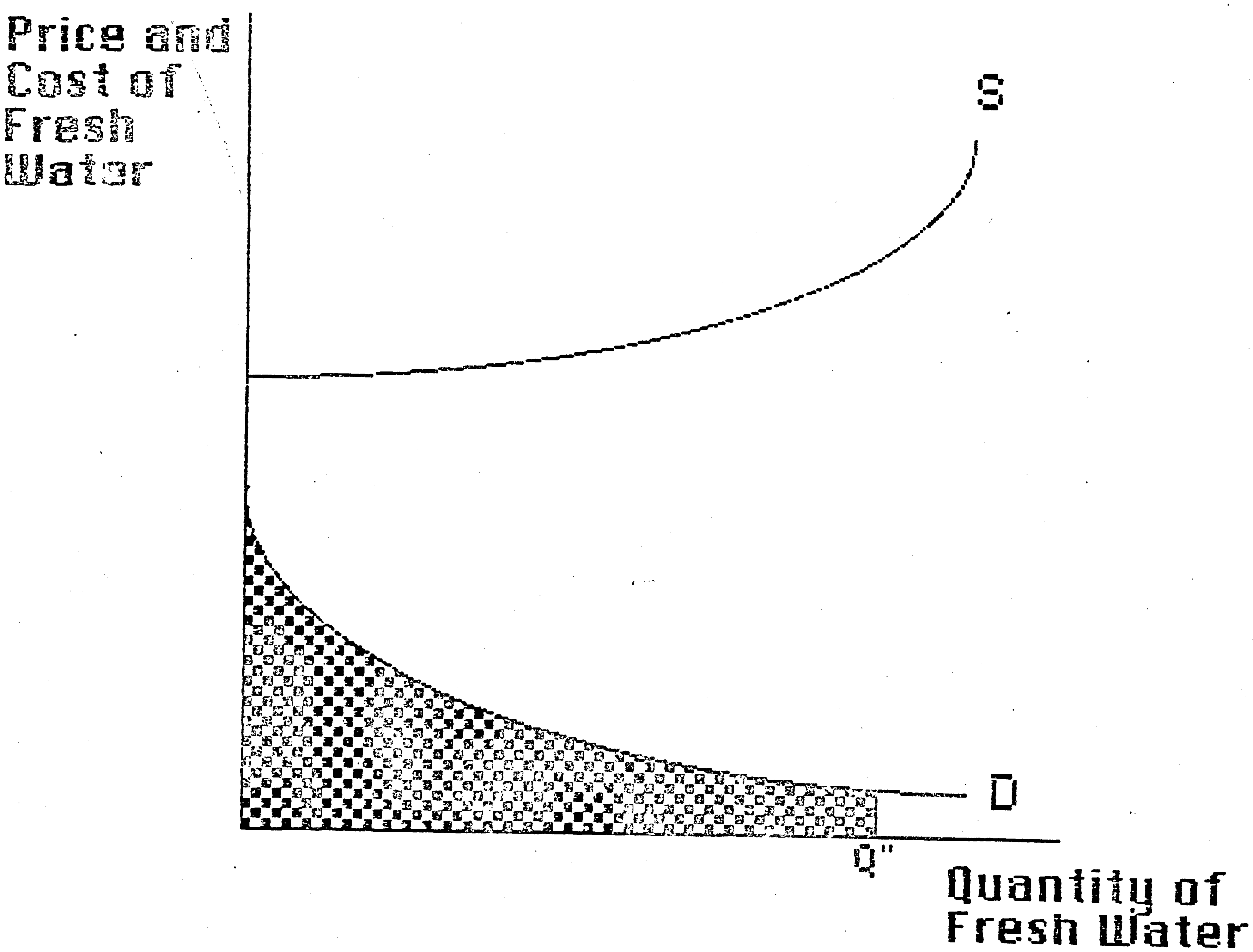

FIGURE 3. Welfare Gain when Product Demand Curve Lies Between Old and New Supply Curves