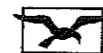


# ECONOMICS of the PUBLIC SECTOR

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THIRD EDITION

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# 1 1 Cost-Benefit Analysis

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## **FOCUS QUESTIONS**

- 1 What is cost-benefit analysis and why is it useful? What are the basic steps in cost-benefit analysis?
  - 2 How does private cost-benefit analysis differ from social cost-benefit analysis?
  - 3 What is consumer surplus and what role does it play in cost-benefit analysis?
  - 4 How does the government value nonmarketed benefits of a project (such as time or lives saved)?
  - 5 What discount rates should be used for valuing future benefits and costs in social cost-benefit analysis?
  - 6 How should risks be treated in cost-benefit analysis? How should distributional concerns be brought into the analysis?
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The preceding chapter set out the basic framework for the analysis of government expenditure policies. In many cases, government wants more than a qualitative analysis; it needs a quantitative analysis. It needs to know not only that there is a rationale for government action; it needs to know

whether the benefits of the particular government action (project, regulation) exceed the costs. For example, should the government:

- Build a bridge and, if so, of what size?
- Construct a dam and, if so, of what size?
- Institute more stringent regulations for flammability of mattresses?
- Institute more stringent regulations for licensing drugs?
- Extend the Washington, D.C., subway system?
- Declare certain portions of the Cape Cod seashore a national park?

This chapter describes how the government goes about making these evaluations. First, however, it is instructive to consider how a private firm makes decisions concerning which projects to undertake.

### PRIVATE COST-BENEFIT ANALYSIS

Private firms continually have to decide whether to undertake investments. The procedures they follow can be characterized in four steps:

- 1 Identify the set of possible projects to be considered. If a steel firm wishes to expand its production capacity, there may be a number of ways it can do this. There may be alternative technologies available for smelting iron ore, and there may be a number of alternative specialized forms of steel that can be produced. The first stage, then, is to list the various major alternatives.
- 2 Identify the full consequences of each alternative. The firm is primarily concerned with its inputs and outputs. Thus, it will determine the labor, iron ore, coal, and other materials required for each production alternative; it will assess the quality of steel that will be produced under each alternative; it will determine the quantity of various wastes that will be produced.
- 3 Assign a value to each input and output. The firm will estimate the costs of various kinds of labor (with various skills) over the lifetime of the plant; the costs of other inputs, such as coal and iron ore; the prices at which it can sell the steel (which will depend on the quality of the steel produced, which may in turn vary from project to project); and the costs of disposing of wastes.
- 4 Add up the costs and benefits to estimate the total profitability of the project. The firm will undertake the project with the highest profit (the maximum difference between benefits and costs)—provided, of course, that profits are positive (taking appropriate account of the **opportunity costs**, the return the firm's resources could obtain elsewhere). If profits for all contemplated projects are negative, the firm will undertake no project; it will invest its funds elsewhere.

### PRESENT DISCOUNTED VALUE

The procedures described above seem simple and straightforward. Only one part requires some elaboration. The benefits and costs of the steel mill occur over an extended period of time. Surely the firm is not indifferent when it comes to choosing between receiving a dollar today and receiving one in twenty-five years. How are the benefits and costs that accrue at different dates to be valued and compared?

The method used is based on the premise that *a dollar today is worth more than a dollar tomorrow*. Suppose the interest rate is 10 percent. If the firm receives \$1 today, it can take it down to the bank, deposit it, and have \$1.10 at the end of the year. Thus \$1 today is worth \$1.10 next year. The firm is just as well off receiving \$1 today as \$1.10 next year. If the firm invests the \$1.10, it will have at the end of the following year \$1.21. Accordingly, the firm is indifferent between receiving \$1 today and \$1.21 in two years' time.

To evaluate projects with receipts and expenditures in future years, the firm multiplies those receipts and payments by a **discount factor**, a number (less than 1) that makes those future receipts and payments equivalent to current receipts and payments. The discount factor is smaller the further into the future the benefit is received. The discount factor for payments in one year is just  $1/(1+r)$ , where  $r$  is the rate of interest<sup>1</sup> (in our example  $r = .10$ , so the discount factor is  $1/1.1 = .9$ ); for payments in two years' time it is just  $1/(1+r)^2$  (in our example it is  $1/1.21$ ). The value *today* of \$100 to be received two years in the future is thus  $\$100/1.21 = \$82.64$ . We then add up the value of what is to be received (or paid out) in each year of the project. The sum is called the **present discounted value** of the project, often abbreviated as PDV. If  $R_t$  is the *net* receipts from the project in period  $t$ , and  $r$  the rate of interest, then if the project lasts for  $N$  years, its PDV is given by

$$PDV = R_0 + \frac{R_1}{1+r} + \frac{R_2}{(1+r)^2} + \dots + \frac{R_t}{(1+r)^t} + \dots + \frac{R_N}{(1+r)^N}$$

Table 11.1 provides an illustration of how this might be done for a hypothetical steel mill lasting five years. (Most steel mills last much longer than that; this makes the calculations more complicated, but the principle is the same.) For each year, we multiply the net receipts of that year by the discount factor for that year. Notice the large difference between undiscounted profits (\$1000) and discounted profits (\$169). This difference is

<sup>1</sup> To see this, compare what the firm has at the end of the year if it receives  $\$100 \times 1/(1+r)$  today. It takes the  $\$100 \times 1/(1+r)$  and invests it, receiving a return of  $r$ . Thus, at the end of the year, it has

$$\begin{aligned} & \$100 \times 1/(1+r) \quad \text{the original amount} \\ + & r \times \$100 \times 1/(1+r) \quad \text{the interest} \\ & (1+r) \times (\$100 \times 1/(1+r)) = \$100. \end{aligned}$$

Therefore, the firm is indifferent between receiving  $\$100 \times \frac{1}{1+r}$  today, and \$100 next year.

**TABLE 11.1**  
Hypothetical Calculation  
of Profitability for  
a Five-Year Steel Mill

YEAR	BENEFITS (RECEIPTS)	COSTS	NET PROFITS	DISCOUNT FACTOR	NET DISCOUNTED PROFITS
1		3000	-3000	1	-3000
2	1200	200	1000	$\frac{1}{1.1} = .909$	909
3	1200	200	1000	$\frac{1}{1.1^2} = .826$	826
4	1200	200	1000	$\frac{1}{1.1^3} = .751$	751
5	1200	200	1000	$\frac{1}{1.1^4} = .683$	683
Total	4800	3800	1000		169

likely to be particularly large for long-lived projects entailing large initial investments; the benefits for such projects occur later in time (and are therefore worth less) than the costs, which occur earlier in time.

### SOCIAL COST-BENEFIT ANALYSIS

The government goes through basically the same procedures in evaluating a project. There are, however, two critical differences between social and private cost-benefit analyses.

First, while the only consequences of a project that are of concern to the firm are those that affect its profitability, the government may be concerned with a much broader range of consequences. For example, it may be concerned with the ecological effects of a dam, and with the impact of the dam on the river's recreational uses.

Second, whereas the firm uses market prices to evaluate what it has to pay for its inputs and what it receives for its outputs, there are two instances in which the government might not use market prices in evaluating projects: (a) When the outputs and inputs are not sold on the market, market prices do not exist. Market prices do not exist for clean air, for lives saved, or for the preservation of wilderness in its natural state. (b) When there is a market failure, market prices do not represent a project's true marginal social costs or benefits. The prices the government uses to evaluate its projects must reflect the market failure. (Recall from Chapter 3 that in the absence of market failures, market prices do reflect marginal social costs and benefits; accordingly, in the absence of market failure, the government should use market prices in evaluating its projects.)

Social cost-benefit analysis is concerned with developing systematic ways of analyzing costs and benefits when market prices do not reflect social costs and benefits. In the following sections, we will look at how the government values benefits that are typically not monetized—like the value of the environment, or of lives—and how the government values marketed goods and services when there are reasons to believe that important market failures exist, such as massive unemployment, which result in market prices that do not reflect social benefits and costs.

### CONSUMER SURPLUS AND THE DECISION TO UNDERTAKE A PROJECT

### MAJOR DIFFERENCES BETWEEN SOCIAL AND PRIVATE COST-BENEFIT ANALYSIS

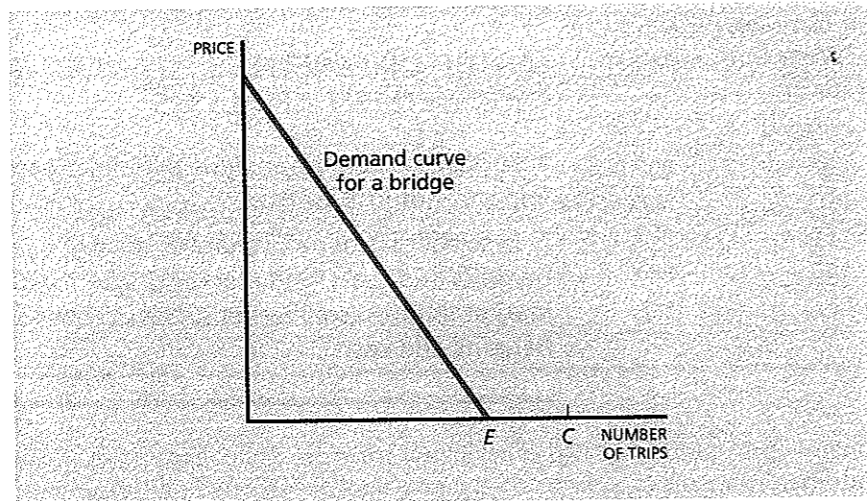
- 1 Social cost-benefit analysis takes into account a wider range of impacts, not just profits.
- 2 In social cost-benefit analysis, market prices may not exist for many benefits and costs, and market prices may not be used because of market failures (so, market prices do not reflect marginal social benefits and costs).

### CONSUMER SURPLUS AND THE DECISION TO UNDERTAKE A PROJECT

Before turning to these issues, there is, however, one other set of situations where cost-benefit analysis plays an important role. Even when the price system is working well, so that prices reflect marginal benefits and costs, a project may not break even—and thus would not be provided by the market—and yet total benefits exceed costs, so the project *should* be undertaken. Typically, these are projects that have large fixed costs, such as a bridge, or more generally, projects that are large enough to have an effect on prices. Thus market prices can be used for valuing projects only when projects are sufficiently small that they have a negligible effect on prices. In the case of a bridge, while it may leave prices in general unchanged, the "price" of crossing the river at that particular place can be thought of as being reduced from infinite (the good simply is not available) to zero.

Figure 11.1 shows the demand curve for a bridge. Even at a price of zero, only a certain number of trips across the bridge will be taken—denoted by point *E*. Assume the capacity of a minimal-size bridge is *C*, which exceeds *E*, and that the marginal cost of using the bridge is zero. Then efficient utilization of the bridge requires a zero toll (price); any higher price will restrict usage, when the marginal cost of usage is zero. But clearly, at a zero price, no private firm would undertake the bridge.

But while the marginal value of a trip is zero, the total value of the bridge is clearly positive. The question is, is the total value large enough to offset the costs of the bridge? To find the total value of the bridge, we ask a simple question: How much, in total, would individuals be willing to pay to have the bridge (with a toll of, say, zero)? As we saw in Chapter 5, the total amount that individuals *would be willing to pay* in excess of *what they have to pay* is called the **consumer surplus**. There, we showed that consumer surplus is measured as the difference between the area under the compensated demand curve and what they actually have to pay for the

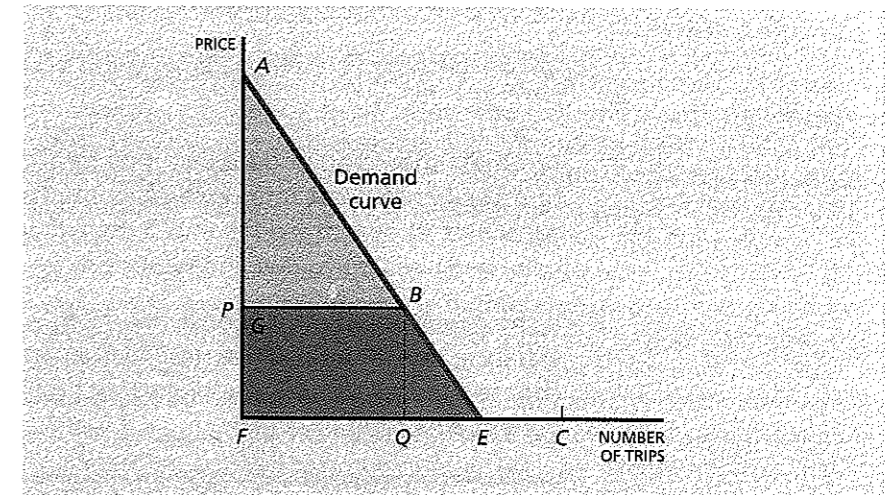


**FIGURE 11.1** Efficient Utilization of a Bridge If the minimum scale capacity for a bridge,  $C$ , exceeds the demand at a zero price,  $E$ , then efficiency requires that no toll be charged, but it still may be worth constructing the bridge.

good.<sup>2</sup> Figure 11.2 shows the compensated demand curve—everywhere along it each individual's welfare is the same as it would have been if no bridge had been constructed. If no tolls were charged, the consumer surplus would be the entire area under the demand curve, the area of the triangle  $AFE$ . This would measure the entire amount that all individuals would be willing to pay to have the bridge—say, the value of the savings in time and driving costs of using that bridge rather than using the

<sup>2</sup> Recall that along the compensated demand curve, the individual's welfare (utility) is constant. The compensated demand curve tells us the quantity of the good which the individual demands at each price if, as the price is lowered, we take away just enough income to leave him no better off as a result of the price decrease. If the individual consumes relatively little of the good, then the amount we have to take away is relatively small. The difference between the compensated and uncompensated demand is the result of the "income effect"—the change in demand (here, for trips) from taking away this small amount of income. Accordingly, the difference between the compensated and uncompensated demand curves for an item like a bridge is typically small. See R. Willig, "Consumer's Surplus without Apology," *American Economic Review* 66 (1976): 589-97. Obviously, in other cases—such as the supply of labor (demand for leisure)—the difference could be large. See J. Hausman, "Exact Consumer's Surplus and Deadweight Loss," *American Economic Review* 71 (1981): 662-76. Whether economists should ignore the income effect or not, in practice they frequently do, because of difficulties in quantifying its magnitude. (As a matter of terminology, the area under the ordinary demand curve is often called the consumer surplus, as opposed to the exact consumer's surplus, the area under the compensated demand curve. The exact consumer's surplus is what is relevant for project evaluation.)

#### CONSUMER SURPLUS AND THE DECISION TO UNDERTAKE A PROJECT



**FIGURE 11.2** Calculation of Consumer Surplus The consumer surplus is the area under the (compensated) demand curve. If a zero toll is charged, the bridge should still be constructed if the consumer surplus exceeds the cost of the bridge. (If a toll of  $P$  is charged, then the consumer surplus is the area  $AGB$ , and the bridge should be constructed if the consumer surplus, which is now only  $AGB$ , plus the revenues raised,  $FGBQ$ , exceed the cost of the bridge.)

bridge one mile downstream. If a toll  $P$  is charged, then the total people are willing to pay still exceeds the amount actually paid by the amount of the triangle  $AGB$ .

The decision to build the bridge is then a simple one: Do the total benefits (revenues plus consumer surplus) exceed the total costs (including any costs incurred in raising the revenue to finance the bridge)?<sup>3</sup>

Sometimes economists look at the ratio of benefits to costs. The criterion for undertaking any project for which benefits,  $B$ , exceed costs,  $C$ ,

$$\text{Undertake a project if } B > C$$

can be rewritten: Undertake any project for which the ratio of benefits to costs exceeds unity:

$$\text{Undertake a project if } B/C > 1.$$

Often, governments must choose which project among several to undertake. There may be a dam site on which only one dam can be constructed.

<sup>3</sup> There is one subtlety: The total costs should include not only the expenditures on the bridge, but the additional costs associated with raising the required tax revenues to finance it.

## COST-BENEFIT ANALYSIS: CRITERION FOR ACCEPTING PROJECTS

A project should be undertaken if its total benefits exceed total costs, or if the benefit-cost ratio exceeds unity. Total benefits include the consumer surplus, the difference between what individuals would have been willing to pay and what they have to pay.

If the government must choose one from among a set of projects (for instance, several alternative designs for a dam to construct), it should choose the project with the highest net benefits, not the highest benefit-cost ratio.

Different dams may have different benefits and costs. In this particular case, the government should undertake the project in which the total *net benefit* from the project, the difference between the benefits and costs, is largest.

Note that choosing the project that maximizes the difference between benefits and costs is *not* the same as choosing the project that maximizes the benefit-cost ratio. A very small project with a small benefit and an even smaller cost could have a very high benefit-cost ratio, and yet yield relatively small net benefits.<sup>4</sup>

### MEASURING NON-MONETIZED COSTS AND BENEFITS

For many of the costs and benefits associated with government projects and regulations—such as lives saved, or environments protected—there are not market prices. Economists have developed systematic procedures for estimating these values. In some cases, such as the value of time, we can make inferences about individuals' evaluations from market data and from their observed behavior in other contexts. In other cases, such as the value of the Grand Canyon, survey techniques have been employed. Many of these valuation techniques remain controversial.<sup>5</sup>

<sup>4</sup> The problem is that we have not included in our cost measure the opportunity cost of the dam site. If we correctly calculate the opportunity cost of the dam site, then there will be only one project for which the benefits exceed the total costs; this is, of course, the same project that we identified before as maximizing the net benefits from the dam site.

<sup>5</sup> For more on determining the benefits of environmental goods, see Maureen L. Cropper and Wallace E. Oates, "Environmental Economics: A Survey," *Journal of Economic Literature* 30 (June 1992): 675-740. Also see the Symposium on Contingent Valuation in the *Journal of Economic Perspectives* 8, no. 4 (fall 1994).

## VALUING TIME

The old adage "time is money" describes how most economists evaluate the savings in time resulting from an improved transportation system, such as a better subway system or road network. The typical approach is to attempt to ascertain the wage rate of those who use the transportation system; under certain ideal conditions, the wage provides a measure of an individual's evaluation of her own time. In simple economic models, an individual is pictured as making a choice between the amount of leisure and the amount of work that she undertakes. As a result of giving up one more hour of leisure, she gets an increase in consumption goods equal to her hourly wage. In equilibrium, she is indifferent when choosing whether to give up one more hour of leisure and increase her consumption by an amount equal to her hourly wage, or to reduce her work (increase her leisure) by an hour and decrease her consumption by an amount equal to her hourly wage. Thus her wage provides a monetary valuation of her time. If a faster subway reduces commuting time by twenty minutes, and the wage is \$9 an hour, the value of the time saved is \$3. We calculate the value of time saved by each individual and add the values together to obtain the total value of time saved.

Some claim that this overestimates the value of time: many individuals would like to work more at their wage rate but are unable to find additional employment at that wage; the job restricts the number of hours that they can work. The individual's valuation of his leisure is thus fairly low; the compensation that would be required for reducing an individual's leisure by one hour is, in this view, much less than the wage that the individual receives for the work that he is able to obtain.

Others claim that the wage may underestimate the value of leisure for some individuals and overestimate the value of leisure for other individuals. They point out that professors, for instance, have chosen a comparatively low-wage job relative to other options available to them because of the great nonmonetary benefits associated with the job. The value of their leisure exceeds the wage they receive. On the other hand, the wage of the coal miner or the garbage collector includes some compensation for the unattractive features of those jobs and hence represents an overestimate of the value of leisure.

## VALUING LIFE

Probably no subject in public cost-benefit analysis has engendered so much emotional discussion as economists' attempts to place a monetary value on life. As distasteful as such a calculation may seem, it is necessary, in a variety of circumstances, for governments to face up to this problem. There is virtually no limit to the amount that could be spent to reduce the likelihood of an accident on a road, or of death from some disease. Yet at some point a judgment must be made that the gain from further expenditures is sufficiently small that additional expenditures are not warranted. An individual who otherwise would not have may die as a result of this decision. Yet we cannot spend 50 percent of our national income on transportation safety, or 50 percent of our national income on health.

## CHILDREN, CAR SAFETY, AND THE VALUE OF LIFE

Even though life is priceless, economists have used the methodologies described in the text (and others) to put a dollar number on it. Different studies produce different results, with a range of between \$1 million to \$20 million, but most studies show numbers at the lower end of that range, between \$2 million and \$8 million (in 1997 dollars).\*

The U.S. government has debated whether to use a single number for cost-benefit analyses in all agencies. So far, different agencies use different numbers—with the Environmental Protection Agency typically using numbers considerably larger than those employed by the Department of Transportation—and larger than those substantiated by most outside studies.

Those who argue against using a single number suggest that there are a number of other factors that should go into the analysis, such as whether the death resulted from an action voluntarily engaged in (such as driving).

One of the most difficult questions in valuing lives is whether the life of a child should be valued differently than the life of an adult, or of an 80-year-old. The issue comes up repeatedly: How should we allocate money between two cancer research programs, one targeting

Two methods have been used for estimating the value of life. The first is the *constructive method*—that is, we estimate what the individual would have earned had he remained alive (until his “normal” age of death). To do this, we extrapolate his employment history, comparing it to that of individuals in similar positions.

This method fails to distinguish between the value of life and the livelihood that goes with it. It thus suggests that after retirement, an individual’s life has zero value, since there is no loss of earnings. This seems clearly wrong. (It confuses means and ends: Income is earned in order to provide

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### ALTERNATIVE METHODS OF VALUING LIFE

**1 Constructive method:** What would the individual have earned had she remained alive?

**2 Revealed preference method:** How much extra income do individuals need to compensate them for an increase in the chance of death, as reflected in market wages for riskier jobs?

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a cancer typically found in children, the other a form of cancer that typically only shows up among the elderly?

The Department of Transportation (DOT) is responsible for imposing regulations to ensure the safety of cars. In imposing regulations, it looks at the costs and benefits. In the mid-1990s, DOT addressed whether to strengthen the standard for car frames that would largely affect deaths in the rear seat in side collisions. A disproportionate fraction of those saved would be children (since they more often ride in the rear seat). This raised the issue of whether to employ a different value of life instead of the one used elsewhere, when those saved were more typically adults. When a child’s life is saved, more “life-years” are saved than when the life of an 80-year-old is saved. DOT has continued to use the traditional method for valuing life, which treats all lives the same. Even so, an alternative methodology, which focused on life-years saved rather than lives, was sanctioned in new federal guidelines established in 1995.

\*For surveys of the value of life, see pages 713–15 in M. Cropper and W. Oates, “Environmental Economics: A Survey,” *Journal of Economic Literature* 30, no. 2 (June 1992): 675–740; and Peter Dorman, *Markets and Mortality: Economics, Dangerous Work, and the Value of Human Life* (Cambridge, England; New York; and Melbourne: Cambridge University Press, 1996).

consumption; producing income is not presumably the *object* of life, and therefore not the basis of valuing it.)<sup>6</sup>

There is an alternative, indirect method that does recognize the natural desire to live longer. In some occupations, there is a much higher chance of death than in others. For instance, the accident rates for coal miners are higher than for college professors, and the death rates for workers in asbestos factories and jackhammer operators are much higher than for clerical workers. Individuals who undertake riskier occupations normally require compensation for assuming these additional risks. By choosing the riskier occupation, they are saying that they are willing to face a higher chance of death for a higher income while they are alive. The second method calculates the value of life by looking at how much extra income individuals need to compensate them for an increase in the chance of death. There is considerable controversy about this second method, however, just as there is about the first. Some believe that it grossly underestimates the value of life; they argue that individuals are not well informed concerning the risks they

<sup>6</sup> For an early critique of this method and one of the first developments of the second, indirect method, see T. Schelling, “The Life You Save May Be Your Own,” reprinted in T. Schelling, *Choices and Consequences* (Cambridge, Mass.: Harvard University Press, 1984).

VALUING NATURAL  
RESOURCES

face.<sup>7</sup> Also, for well-known psychological reasons, individuals attempt to ignore what information they do have concerning the riskiness of their jobs.

As controversial as the estimates of the value of life may be, there appears to be no alternative to using them in the evaluation of projects that affect the likelihood of death.

A question of increasing concern is how to value impacts on the environment. That issue was raised forcefully by the 1989 Exxon *Valdez* oil spill. Network news reports on the millions of dying otters, salmon, and birds brought into every American home the impact of the spill in a relatively remote area. If people had died, it is clear that Exxon would have owed the families huge amounts of money in compensation. Obviously, the relatives of the animals that had been killed had no standing in court to demand compensation. But many Americans felt that Exxon should pay something, both to deter others from taking actions which might damage the environment, and to compensate them for their perceived loss from the environmental injury. Using a relatively new technique called **contingent valuation**, courts valued the compensation that Exxon would have to pay at approximately \$1 billion. This was compensation that went beyond the direct economic injury, for instance, to fishermen who lost their livelihood.

In contingent valuation, individuals are asked a series of questions intended to elicit how much they value the environmental damage or the preservation of some species. Many (but not all) individuals seem willing to pay something, for instance, to preserve whales or the spotted owl or other endangered species, or the Arctic National Wildlife area, even if they themselves do not directly come into contact with the species or do not visit the preservation area. These values are referred to as **existence values**. Even if each individual is willing to pay only a little, say, \$5 or \$10, when added up over all Americans, the values may be significant—in excess of \$1 billion. This is what the court found in the *Valdez* case.

Though there is considerable controversy over the accuracy of these methods, a special panel set up by the National Oceanic and Atmospheric Administration, which included distinguished Nobel Prize winners Kenneth Arrow of Stanford and Robert Solow of MIT, recommended cautious use of the methodology by the government. In 1994, the government proposed new regulations implementing the new methodology.<sup>8</sup>

<sup>7</sup> Several studies have attempted to estimate the magnitude of workers' misperceptions and suggest that they may not be too large. See, for instance, W. K. Viscusi, *Risk by Choice: Regulating Health and Safety in the Workplace* (Cambridge, Mass.: Harvard University Press, 1983).

<sup>8</sup> See M. Common, I. Reid, and R. Blaney, "Do Existence Values for Cost-Benefit Analysis Exist?" *Journal of Environmental and Resource Economics* 9, no. 2 (1997): 225–38; John Duffield, "Nonmarket Valuation and the Courts: The Case of Exxon *Valdez*," *Contemporary Economic Policy* 15, no. 4 (October 1997): 98–110; Kenneth J. Arrow et al., "Is There a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation," *Environment and Development Economics* 2, no. 2 (May 1997): 196–201; and Paul R. Portney, "The Contingent Valuation Debate: Why Economists Should Care," *Journal of Economic Perspectives* 8, no. 4 (fall 1994): 3–17.

SHADOW PRICES AND  
MARKET PRICES

## SHADOW PRICES AND MARKET PRICES

Whenever there is a market failure, market prices may not reflect true marginal social costs or benefits. In such circumstances, economists attempt to calculate the true marginal social costs or benefits—for instance, of hiring an additional worker, or of importing or exporting additional goods. They call these "social prices" or "shadow prices." The term **shadow price** reminds us that while these prices do not really exist in the market, they are the true social costs and benefits, reflected imperfectly in the market price.

In the absence of a market failure, the price of something equals its opportunity cost, what is forgone in alternative uses. In an economy in which there is massive unemployment, the market wage exceeds the opportunity cost—indeed, what is forgone is the individual's leisure—but when workers are unemployed involuntarily, the market wage exceeds the value of this forgone leisure often by a considerable amount. The shadow price of labor when there is massive unemployment is the low value of the forgone leisure, not the market wage.

Similarly, in an economy in which capital markets work very imperfectly, and firms cannot raise additional capital at the "market rate of interest," the shadow cost of capital—what is forgone by using capital in one use rather than another—may exceed the market rate of interest by a considerable amount.

DIFFERENCES BETWEEN MARKET PRICES  
AND SHADOW PRICES

Shadow prices reflect true marginal social costs. When there are market failures, market prices may not fully reflect social costs.

Examples are shown below.

MARKET	DIFFERENCE BETWEEN MARKET AND SHADOW PRICES	EXPLANATION
Labor	Shadow wage is less than market wage when there is unemployment.	No loss in output elsewhere when individual is hired; hence marginal social cost of hiring worker is less than wage.
Capital	Shadow interest rate exceeds market interest when there is rationing in capital markets.	Firm's expected return exceeds interest rate (firm would like to borrow more at given interest rate, but can't). Thus opportunity cost of funds is greater than the interest rate.
Steel	Shadow price exceeds market price.	Steel producer fails to value marginal social cost of pollution resulting from increased production.



## DISCOUNT RATE FOR SOCIAL COST-BENEFIT ANALYSIS

Our discussion of private cost-benefit analysis noted that a dollar next year or the year after is not worth as much as a dollar today. Hence, income to be received in the future or expenses to be incurred in the future have to be discounted. In deciding whether to undertake a project, we look at its present discounted value. The discount rate private firms use is  $r$ , the rate of interest the firm has to pay. What discount rate should the government use? The discount rate used by the government is sometimes called the **social discount rate**. The central question of concern is the relationship between this rate and the interest rate faced by consumers, on the one hand, and the rate faced by producers, on the other.

For evaluating long-lived projects, such as dams, the choice of the discount rate is crucial: a project that looks very favorable using a 3 percent interest rate may look very unattractive at a 10 percent rate. If markets worked perfectly, the market interest rate would reflect the opportunity cost of the resources used and the relative evaluation of income at different dates. But there is a widespread belief that capital markets do not work well. Moreover, taxes may introduce large distortions, with large differences between before- and after-tax returns. Thus it is not clear which of the various market rates of interest, if any, should be used: for instance, should it be the rate at which the government can borrow, or the rate at which the typical taxpayer can borrow?

If the individuals who benefit from the project are the same as those who pay the costs, we can simply use their *marginal rate of substitution*, how they are willing to trade off the reduction in current consumption for gains in future consumption. Since their marginal rate of substitution will be directly related to the rate of interest at which they can borrow and lend, in this case we can use that market rate of interest for evaluating costs and benefits in different periods. But often, the project has further ramifications—a public project may, for instance, displace a private project—and we then have to look at *all* of the consequences, the *net* change in consumption.

If a public project displaces a private project of the same size, then the net reduction in consumption today from the project is zero. If both the public and private projects yield all of their returns in the same period, then we can easily decide whether to undertake the project: we should undertake it if its output exceeds that of the private project; or equivalently, if its rate of return exceeds that of the private project. In this view, which, not surprisingly, is called the **opportunity cost view**—because the private project is the opportunity cost of the public project—it is the producer's rate of return that should be used in project evaluation.

Focusing on opportunity costs and focusing on consumers' marginal rates of substitution yield exactly the same result in economies in which there are no market failures, for then the marginal rate of substitution (which equals the rate of interest facing consumers) equals the rate of return on capital, or the producers' rate of interest (the opportunity cost). Problems arise when there are market failures or taxes; and/or when those

who benefit from a project are different from those who pay for them.<sup>9</sup> Today many economists argue that the appropriate rate of interest for government discounting may be *none* of the observed market rates of interest. More generally, it is recognized that choosing the appropriate interest rate is an exceedingly complex matter.<sup>10</sup>

In the more general case, there is no presumption that the ratio of the marginal valuation of an increase in consumption by one generation to that of another is related to *any* interest rate. One approach, in that case, is to use *social welfare functions*. We first introduced the concept of a social welfare function in Chapter 5 as a way of formalizing how consumption or income of different individuals could be compared. Exactly the same principles apply in comparing individuals over time as in comparing individuals at the same point of time, with one difference. In both cases, there is *diminishing marginal utility*, so that if future generations have higher incomes than the current generation, the marginal valuation of a dollar of consumption to them is lower. But some economists believe that the welfare of individuals of future generations *at the same level of income* should be weighted less than the welfare of the current generation, simply because it exists in the future. The rate at which future generations' welfare should be discounted is referred to as the **pure discount rate**. Other economists, such as the distinguished Cambridge economist Frank Ramsey, argued that all generations should be given equal weight.

<sup>9</sup> There are a few special cases where the fact that the benefits may accrue to different generations poses no problem. If the government has engaged in optimal **inter-generational redistribution of income**, then the marginal value of a dollar to every generation will be equal to the market rate of interest, and so long as the project is relatively small, we can evaluate the marginal benefits received by different generations using market rates of interest, just as we can when the impacts are felt by a single individual. Similarly, if society consists of a set of family dynasties, in which each family optimally redistributes income from the current generation to succeeding generations, then the marginal value of a dollar to every generation should equal the consumer rate of interest. (See R. Barro, "Are Government Bonds Net Wealth," *Journal of Political Economy* 82, 1974: 1095–1117.) The validity of this model has been strongly questioned. It implies, for instance, that when the government ran huge deficits in the 1980s, individuals increased their savings in a fully offsetting way. Thus, it implies that in the absence of these deficits, personal savings would have been negative. For an extensive discussion of these issues, see the symposium in the *Journal of Economic Perspectives* 3, no. 2 (spring 1989).

<sup>10</sup> There are a few special cases where there is a simple and clear solution—for instance, if the *only* imperfection in the market is *optimally chosen taxes* (in later chapters, we shall describe in detail what is entailed by optimal taxes; for now, we simply note that actual tax systems seldom comport even closely with optimal tax structures) then the producer's rate of return should be used in project evaluation. (See P. Diamond and J. Mirrlees, "Optimal Taxation and Public Production," *American Economic Review* 61 (1971): 261–78.) For a discussion showing how even slight changes in assumptions can lead to markedly different conclusions, see J. E. Stiglitz and P. Dasgupta, "Differential Taxation, Public Goods, and Economic Efficiency," *Review of Economic Studies* 39 (1971): 151–74.

## CLIMATE CHANGE AND DISCOUNT RATES

One important policy issue facing the world over coming decades will be how to respond to the threat of global warming as a result of the increased concentrations of greenhouse gases (such as carbon dioxide) in the atmosphere. The effects go beyond just an increase in temperature: there are concerns about the rise in the level of seawater and increased weather variability.

A series of scientific panels (the International Panel on Climate Change—the IPCC) was convened to assess the scientific evidence concerning global warming. Atmospheric concentrations of greenhouse gases had increased substantially since the beginning of the industrial revolution (mainly as a result of the burning of fossil fuels for energy)—and if unabated would within 150 years exceed two to three times the level at that time. Though no one could be sure about the magnitude of the effects on the climate, there was a consensus that it could be significant. While some cold-climate countries might gain, on average there would be losses, and for some countries—low-lying countries such as Bangladesh and the Pacific Islands—the impact could be disastrous. The reports of the IPCC led to increasing consensus that concerted international action was required, and in 1992 the nations of the world signed an agreement at Rio de Janeiro (called the Rio Convention) intended to reduce the emissions of carbon dioxide and other greenhouse gases. The U.S. Senate ratified the Rio Convention in 1992. In 1997 in Kyoto a further agreement was signed, calling for binding commitments of the industrialized countries to reduce their emissions of greenhouse gases below their 1990 levels. As this book goes to press, prospects for ratification of the Kyoto Convention by the U.S. Senate remain bleak.

In spite of these agreements, within the United States there has been controversy about what should be done about greenhouse gases—how much should be spent to reduce emissions. The controversy arises

To see what is implied by this approach, assume that per capita income is increasing at the rate of 1.5 percent, and the *elasticity of marginal utility* is 1. (The elasticity of marginal utility is the percentage decrease in marginal utility from a 1 percent increase in consumption. As we saw in Chapter 5, economists usually assume the elasticity of marginal utility is between 1 and 2.) Then if the pure discount rate is zero, the social rate of discount is 1.5 percent, roughly equal to the real interest rate on safe (government) securities, but considerably below the opportunity cost of capital.

in part because of discounting: most of the effects of global climate change will not be felt for 100 years—and at a 7 percent discount rate, the value of \$100 a hundred years from now is less than 10 cents. It clearly won't be worth spending much today to avert even large costs in the future. On the other hand, at a 1 percent discount rate, \$100 a hundred years from now is worth more than \$30.

A special working group of economists of the IPCC, including Nobel Prize winner Kenneth Arrow and the chairman of the Council of Economic Advisers of the United States, Joseph Stiglitz, argued that the appropriate methodology implied using a low interest rate for purposes of discounting for costs and benefits associated with climate change.\* Future generations would be adversely affected if actions mitigating the pace of emissions of greenhouse gases were not undertaken, and there were no ethical grounds for valuing their welfare substantially less than the welfare of the current generation. Critics of this view argued that future generations could be made whole, "simply" by setting aside money today, investing it at the market rate of interest, and letting the amount accumulate to be used to address the costs of climate change. The worry, however, was that not only might estimates of future damage repair costs be too low, and more fundamentally, that there might be some damage that was irreparable at any cost, but also that countries would not set aside the funds. If they did not, then the appropriate trade-off was that analyzed by the IPCC committee, between consumption of the current generation and the welfare of future generations which would be adversely affected by climate change.

\**Climate Change 1995: Economic and Social Dimensions of Climate Change*. Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Edited by J. Bruce, Hoesung Lee, and E. Haites. (Cambridge, England, and New York: (Cambridge University Press, 1996.) More information on the IPCC can be found on the Internet at: <http://www.usgcrp.gov/ipcc/>

The question of the appropriate social rate of discount has become a hotly contested political issue. Those who are concerned about the environment and who see environmental impacts stretching out over decades, for example, believe strongly in low discount rates. For instance, in their view, simply because the effects of nuclear waste can be postponed for fifty or a hundred years is no reason to essentially ignore them—which a 10 percent discount rate effectively tells us to do.

Today, the federal government uses a 7 percent discount rate as its basic "guideline." This partially reflects the opportunity cost view—the *aver-*

age rate of return across all sectors of the economy is estimated to be around 7 percent. But for long-lived projects, particularly where there are long-lived environmental impacts, it is likely that lower interest rates will be used in the future.<sup>11</sup>

**TABLE 11.2**  
Sources of  
Disagreement in  
Discount Rates

HIGH DISCOUNT RATE (OPPORTUNITY COST OF CAPITAL)	LOW DISCOUNT RATE (SOCIAL RATE OF DISCOUNT)
1 Government investment tends to displace private investment.	1 Assessing <i>net</i> impacts is typically far more complicated than just assuming a dollar of public investment displaces a dollar of private investment.
2 Even in a world with distortions, everyone could be made better off if efficiency is maintained—this entails the rate of return on public projects' equaling that on private projects.	2 Assessing the desirability of a project must take into account <i>intergenerational distributional</i> effects as well as <i>efficiency</i> effects. a) Programs' beneficiaries are often different from those who bear the costs. b) Even if the government <i>could</i> in principle make everyone better off, the required compensations (for instance, to those who are adversely affected) are seldom made.
3 Even in the absence of government intergenerational redistributions, if parents leave bequests to their children, marginal valuations of consumption of different generations will be equalized (the dynastic model).	3 In the absence of optimal intergenerational redistribution, market rates of interest do not reflect marginal social valuations of dollars to different generations. Further, the dynastic model is implausible.
4 When market distortions are caused by optimal taxes, then efficiency is still desirable, so the government should use the opportunity cost of capital.	4 With market distortions, marginal rates of substitution (how individuals value a marginal dollar in different years) and marginal rates of transformation (the trade-offs facing firms) may differ markedly. With distortionary taxes, efficiency—as exemplified by using the private sector's opportunity cost of capital in the public sector—is desirable only under highly restrictive conditions.

<sup>11</sup> The guidelines for cost-benefit analysis issued by the federal government in 1995 allowed for the use of lower discount rates for long-lived projects with impacts over many generations.

### THREE VIEWS ON THE SOCIAL DISCOUNT RATE

- 1 Reflects consumers' rate of time preference (the consumers' borrowing rate).
- 2 Reflects opportunity cost of capital (the producers' borrowing rate).
- 3 May reflect neither: for example, in long-lived projects affecting different generations, where social marginal valuation of consumption of different generations may have nothing to do with observed interest rates, in the absence of optimal intergenerational redistribution of income.

It is not surprising that the discount rate should be a subject of such *political* controversy. But why can't economists agree among themselves? Our discussion has highlighted several sources of disagreement about the economy and about the government, summarized in Table 11.2.

### THE EVALUATION OF RISK

The most common mistake in trying to cope with the uncertainties of the benefits and costs of a project is to argue that in the face of risk, the government should use a higher discount rate. Recall that the discount rate relates the value of a dollar at one date to its value at a later date. To see how increasing the discount rate may lead to absurd results, consider a project that, at termination, requires an expenditure (say, an automobile has to be towed to the junkyard). Assume that there is some uncertainty about the magnitude of that cost. We would normally think that this uncertainty would make the project less attractive than if we knew for sure what the termination costs were. But consider what happens if we use a higher discount rate to offset the risk: the discount factor is lower, the present value of those costs is reduced, and the project looks more, not less, attractive. To use a higher discount rate confuses the evaluation of income at different dates with the evaluation of risk; these are two separate issues.

To evaluate risks, economists introduce the concept of **certainty equivalents**. Assume there is some risky project. Next year the output of the project may be worth \$0 or \$100; there is a fifty-fifty chance of each outcome. The *average* value is just \$50 ( $\frac{1}{2} \times \$100 + \frac{1}{2} \times \$0 = \$50$ ). If we dislike risk, however, we would clearly prefer a project whose return was a certain \$50. In fact, we would prefer a project with a smaller average value, so long as the risk was smaller. If we would be indifferent in choosing between the risky project with an average value of \$50 and a perfectly safe project with a value of \$45, we would say that \$45 is the certainty equivalent of the risky project

with an average value of \$50. To evaluate risky projects, then, we simply take the present discounted value of the certainty equivalents.<sup>12</sup>

Thus risky projects have to earn a higher return than safe projects with the same certainty equivalent to be acceptable. The extra amount a risky project must earn to compensate is its **risk premium**.

We illustrate the procedure in Table 11.3, for a five-year project. We have assumed that the initial investment in the first period is certain. The benefits that accrue in years 2, 3, and 4 are increasingly uncertain, reflected in the certainty equivalents. The final year, the project is scrapped; there are large costs associated with the termination of the project. (Consider the problem of what to do with a nuclear power plant when its useful life has come to an end.) But these costs are uncertain. Hence its certainty equivalent exceeds the \$50 expected cost. (In contrast, had we employed a higher time discount rate to take account of risk, these uncertain scrapping costs would not have weighed very heavily in our cost-benefit calculation.)

To obtain the present discounted value of the certainty equivalent net benefit at any date, we multiply it by the time discount factor. To obtain the present discounted value, we add up the discounted certainty equivalent net benefits for the life of the project.

How should the government evaluate the risks associated with various projects? In some cases, such as the risks associated with the generation of electricity, it can look to how private markets value risks. But for risks for which there is no comparable private project, matters are more difficult. Some, such as a flood control project, serve to *reduce* the risks individuals face, and for these projects, the risk premium is negative. Individuals are willing to pay something to reduce the risk of flood. Since the government can spread risks over the entire population, when the project neither serves an insurance function (reducing the risks individuals would other-

**TABLE 11.3**  
Example of Cost-Benefit  
Analysis for Risky  
Investment

YEAR	EXPECTED NET BENEFIT	CERTAINTY EQUIVALENT NET BENEFIT	TIME DISCOUNT FACTOR (10 PERCENT INTEREST RATE)	DISCOUNTED VALUE OF CERTAINTY EQUIVALENT NET BENEFIT
1	\$-100	\$-100	1	\$-100
2	100	90	.91	81.90
3	100	80	.83	66.40
4	100	75	.75	56.25
5	-50	-75	.68	-51
Total	150	70		53.55

<sup>12</sup> This methodology is not perfectly general. It requires that we be able to separate the analysis of risk at one date from that at other dates. For most practical purposes, however, it is sufficiently general.

wise face) nor provides a return that is correlated with income from other sources (that is, the return to the project is neither particularly high nor particularly low when the economy is, say, healthy), the government should employ no risk premium.

#### RISK ASSESSMENT

An area of increasing scrutiny—and controversy—in risk analysis is the risks to health, safety, and indeed life, that are posed, for instance, by hazardous wastes, pesticides, and fungicides. Chemicals in the water and air increase the likelihood of cancer and a variety of other ailments, often life-threatening. About this there is little doubt. The debate has focused on **risk assessment**, on how the magnitude of these risks is assessed and how priorities for reducing these risks should be established.

For instance, many risks are related to exposure. A chemical in dirt that is sealed under a thick layer of concrete is unlikely to impose significant risks; there would be a much higher risk if that same dirt were directly ingested by a child. In assessing the overall risk, one must take into account the probability of different levels of exposure, as well as the risks associated with each level of exposure.

The Environmental Protection Agency, in setting its priorities and its standards—for instance, for cleaning up hazardous wastes—has been criticized on several grounds. Rather than analyzing the effects of compounding of probabilities in the way that students are typically taught in modern statistics courses, the EPA uses a “worst case scenario analysis,” which looks at the risks associated with the worst case. For example, what would be the risk assuming that the concrete seal around the dirt cracked, and a child wandered into the site? There have been some famous stories of the EPA insisting on cleanups to the standard that a child could eat the dirt for a six-week period without having any significant increase in health risk.<sup>13</sup> In setting priorities, there has been concern that the government has not gone after the highest risks, but rather the risks which have the most “popular appeal.” The risks that are addressed by the EPA are often far lower than the risks which individuals take in their day-to-day lives, for instance, from drinking alcohol moderately, let alone from smoking. There is, however, one critical distinction: The risks upon which the EPA focuses are those (like air and water pollution) over which individuals have no choice; they are incurred involuntarily, as opposed to the risks associated with smoking and drinking. Still, the fact that individuals seem willing to incur certain risks reveals information about their *valuation* of the risks, a fact which government should presumably take into account when adopting environmental risk standards. Recent government regulations have put greater emphasis on assessments of comparative risks; there is a reluctance to impose costly regulations to reduce risks which are of the size that individuals seem willing to accept in ordinary circumstances.

<sup>13</sup> See Stephen G. Breyer, *Breaking the Vicious Circle: Toward Effective Risk Regulation* (Cambridge, Mass.: Harvard University Press, 1993), p. 12.

There has been increasing concern that environmental risks are borne disproportionately by the poor, who often live in industrial areas with heavier pollution. This is not surprising, since land in such areas typically is less valuable, so that they can obtain housing at lower costs. Early in 1994, President Clinton signed an executive order on **environmental justice**, instructing agencies to ascertain the distributional impact of various environmental measures that they might undertake.

### DISTRIBUTIONAL CONSIDERATIONS

The benefits of any given public project are not uniformly distributed across the population. Some projects, such as a dam, have benefits that are limited geographically. Other projects, such as the bilingual education program and jobs retraining program, are directed mainly at the poor. The government is clearly concerned about the impact of its programs on the distribution of income.

Should these distributional effects be taken into account in cost-benefit analysis? If so, how can they be quantified?

The issue of whether government should take distributional effects into account is analogous to the issue of whether, in choosing a social discount rate, the government needs to be concerned with the impact on different

### KEY ISSUES IN MEASURING A PROJECT'S BENEFITS

- 1 Measuring consumer surplus
- 2 Measuring non-pecuniary benefits:
  - Valuing time
  - Valuing life
  - Valuing the environment
- 3 Valuing marketed goods in the presence of market failure:
  - Using shadow prices to measure marginal social costs when market prices do not accurately measure it
- 4 Valuing consumption (output) at different dates:
  - Choosing the right discount rate
- 5 Valuing risk
- 6 Valuing distributional considerations:
  - How are impacts on different groups to be compared?

### COST EFFECTIVENESS

generations. *If* the government has already "optimally" redistributed income, then the "social" marginal value of a dollar to all individuals is the same, and we can simply add up the dollar value of the impacts on consumption of different individuals. But there is a widespread presumption that the social marginal value of a dollar to a poor individual is greater than it is to a rich individual.

The first step in any distributional analysis is to ascertain as precisely as possible how the program affects individuals in different circumstances. Typically, the focus is placed on individuals of different incomes, though frequently regional impacts are also taken into account. Of two programs with similar overall impact, the one in which more of the benefits and fewer of the costs accrue to poor individuals would presumably be preferred, if society cares about distribution.

Often, however, there is a desire to go beyond simply enumerating the impacts on different groups, to obtain a broader picture. This is done in two different ways. The first uses the social welfare function approach referred to earlier. It recognizes that the marginal valuation of a dollar is greater to a poor person than to a rich person, and uses the concept of the elasticity of marginal utility to quantify the extent to which this is so. For example, using an elasticity of unity (1), and giving a weight of unity to those at median income, impacts on those with half median income receive a weight of 2, while impacts on those with twice median income receive a weight of  $\frac{1}{2}$ . Using these weights, the total "weighted benefit" is calculated, and of two programs with the same costs, the one with the highest weighted benefit is undertaken.

The second approach looks at the impact on the overall distribution of income or wealth.<sup>14</sup> But this approach lends itself only to major programs with the capacity for substantial distributional effects, such as changing the welfare system or the tax system. Most projects undertaken by the government are smaller in scale.

### COST EFFECTIVENESS

In some cases, there are difficulties in comparing costs and benefits. The benefits may be improved health, the costs are dollars expended. Though we have emphasized the necessity of making hard—monetary—judgments concerning life and health, the political process often tries to avoid making such judgments, where possible. **Cost effectiveness** analysis provides a way of doing this by looking at programs with the same (or similar) benefits, and asking which produces those benefits at the least cost.

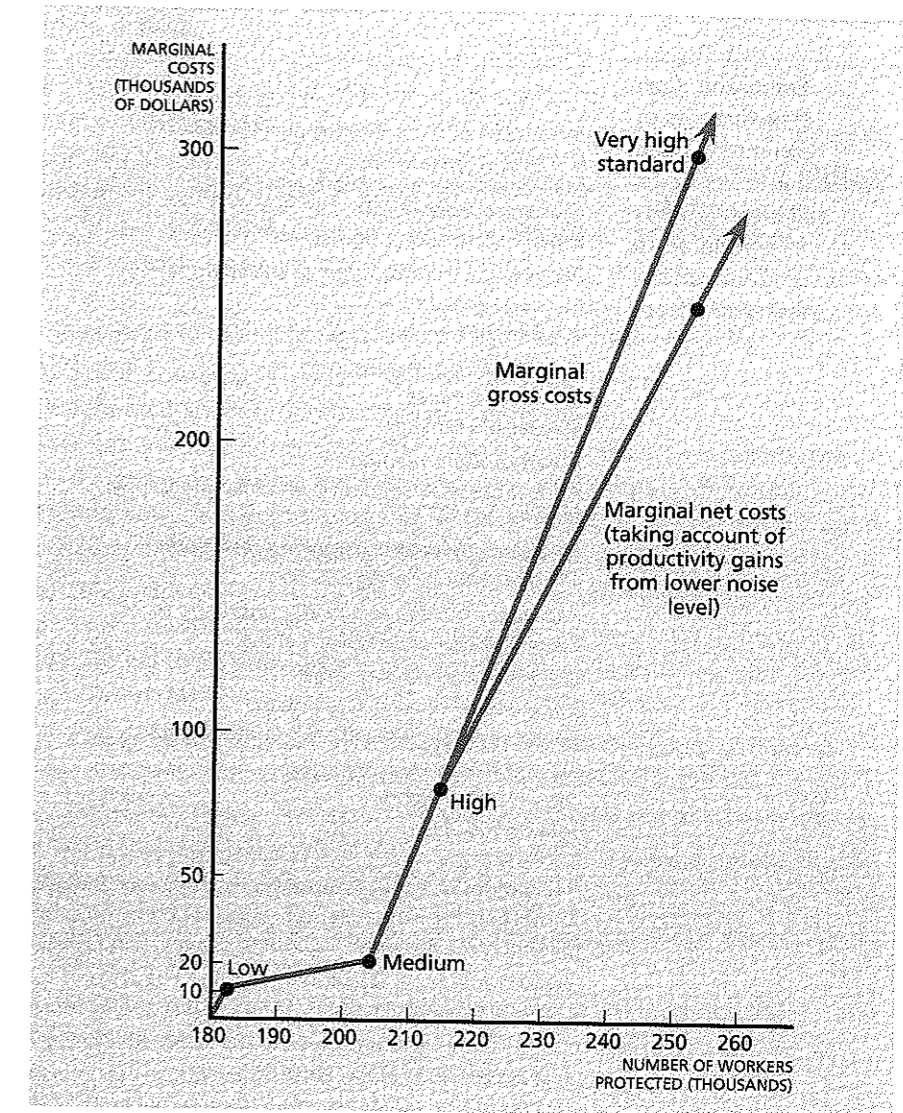
<sup>14</sup> This approach relies on measures like the Gini coefficient, discussed in the appendix to Chapter 5.

Assume that we wish to avoid the problems associated with valuing lives while helping the government assess a variety of ways of reducing highway deaths. We could calculate the costs associated with each of several methods of accomplishing the same goal. Or we might simply show the marginal costs associated with incremental reductions in the death rate under each method, and leave it to the legislators to determine which point along the curve should be chosen (and therefore what method of improving traffic safety should be chosen).

When the Occupational Safety and Health Administration considered standards for noise pollution, it did a cost effectiveness study, calculating how many extra workers would be protected from hearing loss as a result of alternative standards. It then calculated the cost associated with each standard. From this information, it calculated the marginal gross and net costs (taking into account the fact that hearing losses reduce productivity) associated with different levels of protection, as depicted in Figure 11.3. The curve shows that there are significant extra costs of trying to protect additional individuals from hearing loss. On the basis of this, one study concluded, "an effectively administered hearing-protector program could provide most of the benefits at much lower cost in comparison with an industrywide engineering-only noise standard. . . . an 85-decibel hearing-protector standard [has] the relatively reasonable marginal cost of about \$23,000 per hearing impairment avoided. . . ." In ordinary English, the study recommended the use of ear plugs rather than the drastic changes in plants and equipment that would be required to implement the same level of hearing protection. Table 11.4 shows another example of cost effectiveness studies, this time comparing the effectiveness of alternative medical interventions (see page 296). There is an enormous range of cost effectiveness ratios, from \$2158 per life-year saved for administering a low dose of the drug lovastatin to reduce cholesterol for heart attack survivors between 55 and 64 who had a high cholesterol level, to \$41,000 for annual breast examination and mammography for females, age 55-65, to \$88,000 for a coronary artery bypass graft for someone with a single-vessel disease with moderate heart weakness, to \$335,000 for the use of an exercise cardiogram as a screening test for heart disease for 40-year-old females.

Though cost effectiveness analysis is simpler than cost-benefit analysis, because it avoids all the problems of measuring and valuing benefits, most of the issues discussed in measuring and valuing benefits remain, scaled down, for measuring and valuing costs. For instance, shadow prices for inputs may differ from market prices; a social discount rate must be used to value costs incurred at different dates; and there is considerable uncertainty—for example, we might be unsure of the exact degree to which hearing loss hurts productivity, or how much it will cost to bring a new weapon to completion, or how much it will cost firms to comply with stricter environmental standards.

Cost-benefit and cost effectiveness analysis are important tools used by policy makers throughout the world. They provide discipline to the decision-making process. While critics complain that they reduce everything to cold calculations, they can be used to bring systematically into the analysis



**FIGURE 11.3** Comparison of Alternative Standards for Occupational Noise Exposure  
Higher standards cost more and protect more workers from hearing loss.

SOURCE: J. R. Morrall III, "Exposure to Occupational Noise," in *Benefit-Cost Analyses of Social Regulation*, ed. James C. Miller III and Bruce Yandle (Washington, D.C.: American Enterprise Institute for Public Policy Research, 1979).

not only economic costs and benefits, but also concerns about the environment, health, and distribution. While there never will be complete precision, especially in these hard-to-quantify areas, judgments will be made weighing these various considerations, and quantification can be a helpful step in resolving the complicated trade-offs that have to be faced.

**TABLE 11.4**  
**Estimated Cost**  
**Effectiveness of**  
**Commonly Used**  
**Medical Interventions.**  
**(all interventions**  
**compared to**  
**"usual care" unless**  
**otherwise noted)**

INTERVENTION	COST/LIFE-YEAR (\$1993)
<i>Low-dose lovastatin for high cholesterol</i> <sup>a</sup>	
Male heart attack survivors, age 55-64, cholesterol level $\geq$ 250	2,158
Male heart attack survivors, age 55-64, cholesterol level < 250	2,293
Female nonsmokers, age 35-44	2,023,440
<i>Exercise electrocardiogram as screening test</i> <sup>b</sup>	
40-year-old males	124,374
40-year-old females	335,217
<i>Hypertension screening</i> <sup>c</sup>	
40-year-old males	27,519
40-year-old females	42,222
<i>Breast cancer screening</i> <sup>d</sup>	
Annual breast examination and mammography, females age 55-65	41,008
<i>Physician advice about smoking cessation</i> <sup>e</sup>	
1% quit rate, males age 45-50	3,777
<i>Pap smear starting at age 20, continuing to 74</i> <sup>f</sup>	
Every 3 years, versus not screening	24,011
<i>Coronary artery bypass graft</i> <sup>g</sup>	
Left main coronary artery disease	8,768
Single-vessel disease with moderate angina	88,087
<i>Neonatal intensive care units</i> <sup>h</sup>	
Infants 1000-1500 g	10,927
Infants 500-999 g	77,161

<sup>a</sup> L. Goldman, M. C. Weinstein, et al., "Cost-Effectiveness of HMG-CoA Reductase Inhibition for Primary and Secondary Prevention of Coronary Heart Disease," *Journal of the American Medical Association*, 265 (1991): 1145-51.

<sup>b</sup> H. C. Sox, Jr., B. Littenberg, et al., "The Role of Exercise Testing in Screening for Coronary Artery Disease," *Annals of Internal Medicine*, 110 (1989): 456-69.

<sup>c</sup> B. Littenberg, A. M. Garber, et al., "Screening for Hypertension," *Annals of Internal Medicine* 112 (1990): 192-202.

<sup>d</sup> D. M. Eddy, "Screening for Cervical Cancer," *Annals of Internal Medicine* 113 (1990): 214-26.

<sup>e</sup> S. R. Cummings, S. M. Rubin, et al., "The Cost-Effectiveness of Counseling Smokers to Quit," *Journal of the American Medical Association* (1989) 261: 75-79.

<sup>f</sup> D. M. Eddy, "Screening for Breast Cancer," *Annals of Internal Medicine* 111 (1989): 389-99.

<sup>g</sup> M. C. Weinstein, "Economic Assessment of Medical Practices and Technologies," *Medical Decision Making* 1 (1981): 309-30.

<sup>h</sup> M. H. Boyle, G. W. Torrance, J. C. Sinclair, and S. P. Horwood, "Economic Evaluation of Neonatal Intensive Care of Very-Low-Birth-Weight Infants," *New England Journal of Medicine* 308 (1983): 1330-37.

SOURCE: Alan M. Garber and Charles Phelps, "Economic Foundations of Cost-Effectiveness Analysis," *Journal of Health Economics* 16, no. 1 (1997): 1-31.

## REVIEW AND PRACTICE

### SUMMARY

- 1 Cost-benefit analysis provides a systematic set of procedures by which a firm or government can assess whether to undertake a project or program and, when there is a choice among mutually exclusive projects or programs, which one to undertake.
- 2 Private cost-benefit analysis entails determining the consequences (inputs and outputs) associated with a project, evaluating these using market prices to calculate the net profit in each year, and, finally, discounting profits in future years to calculate the present discounted value of profits.
- 3 Social cost-benefit analysis involves the same procedures as private cost-benefit analysis, except that a broader range of consequences is taken into account, and the prices at which inputs and outputs are evaluated may not be market prices, either because the inputs and outputs are not marketed (so market prices do not exist) or because market prices do not accurately reflect marginal social costs and benefits, due to a market failure.
- 4 When the government makes available a good or service that was not previously available (e.g., constructs a bridge across a river), the value of the project to an individual is measured by the consumer surplus it generates; this is the area under the (compensated) demand curve.
- 5 The government has to make inferences (based on market data or observed behavior) concerning the valuation of nonmarketed consequences—e.g., lives and time saved, or impacts on the environment.
- 6 The rate of discount used by the government to evaluate projects may differ from that used by private firms.
- 7 To evaluate risky projects, the certainty equivalent of the benefits and costs needs to be calculated.
- 8 Distributional considerations may be introduced into evaluations, either by weighting the benefits accruing to different groups differently or by assessing the impact of the project on some measure of inequality.

### KEY CONCEPTS

Opportunity costs	Opportunity cost view
Discounting, discount factor	Intergenerational distribution
Present discounted value	Pure discount rate
Consumer surplus	Certainty equivalent
Contingent valuation	Risk premium
Existence values	Risk assessment
Shadow prices	Cost effectiveness
Social discount rate	

**QUESTIONS  
AND PROBLEMS**

- 1 Consider a project that costs \$100,000 and yields a return of \$30,000 for five years. At the end of the fifth year, there is a cost of \$20,000 to dispose of the waste from the project. Should the project be undertaken if the discount rate is 0? 10 percent? 15 percent? The interest rate at which the net present discounted value of the project is zero is referred to as the *internal rate of return* of the project.
- 2 Assume there is uncertainty about the costs of disposing of the waste: there is a fifty-fifty chance that they will be \$10,000 or \$30,000. Discuss how this uncertainty affects the cost-benefit calculation, if the government is risk neutral, that is, it requires no risk premium to compensate it for bearing risk; if it is very risk averse, that is, if it requires a large risk premium to compensate it for bearing risk.
- 3 Assume now that there are two groups in the population. Each contributes equally to the cost of the project, but two-thirds of the benefits accrue to the richer group. Discuss how this alters the cost-benefit calculation. Under what circumstances will the decision to undertake the project be altered?
- 4 Assume that the government now has a choice between undertaking the project described in problem 1 and undertaking a larger project. If it spends an additional \$100,000, returns will be increased by \$25,000 per year and disposal costs in the final year will increase by \$20,000. Which project should be undertaken if the discount rate is 0? 10 percent? 15 percent? In the case where there are two groups in the population, how are your answers affected if two-thirds of the incremental benefits go to the poor (with the incremental costs being shared equally, as before)?
- 5 Discuss why, under each of these circumstances, a social cost-benefit analysis might differ from a private cost-benefit analysis:
  - a The unemployment rate is 10 percent.
  - b The government has imposed a tariff on the importation of textiles.
  - c The government has imposed a quota on the importation of oil.
  - d The government has imposed a tax on interest income.
  - e The government has imposed price controls on natural gas.
  - f The government has regulated airlines, so that prices exceed the competitive levels.
- 6 For each of the following projects, what benefits or costs might be included in a social cost-benefit analysis that might be excluded from a private cost-benefit analysis:
  - a A hydroelectric project
  - b A steel mill
  - c A chemical plant

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- d A project to improve car safety
  - e A training program to improve the skills of minority workers in a firm
- How might your answers be affected by changes in legislation (e.g., concerning manufacturers' liabilities for automobile accidents, legislation imposing fines on polluters)?
- 7 How might the techniques used to analyze the distributional consequences in cost-benefit analysis be employed to ensure that concerns about environmental justice are incorporated into the analysis?
  - 8 How are issues of incidence analysis and capitalization (discussed in the previous chapter) incorporated into cost-benefit analysis? For each case below, does it make a difference to your answer whether poor individuals own or rent their houses? In particular, if you wished to incorporate the distributional consequences of the following policies and programs, how might you do so?
    - a A government regulation which reduces the allowable level of noise for aircraft. (Assume that those who live in the neighborhood of the airport are relatively poor.)
    - b A subway line intended to make it less expensive for those in low-income neighborhoods to get to jobs in the center city.
    - c The Superfund program is intended to clean up toxic waste sites. Currently, a disproportionate number of poor people live near toxic waste sites.
  - 9 The government is debating whether to spend \$100 billion to reduce global warming damage 100 years from now. It is estimated that \$800 billion of damage will be averted. A critic of the expenditure says that it would be far better to take the \$100 billion, invest it in the stock market, earning an average return of 6 percent per year, and use the proceeds of the investment in 100 years to repair the damage. Should the project be undertaken?