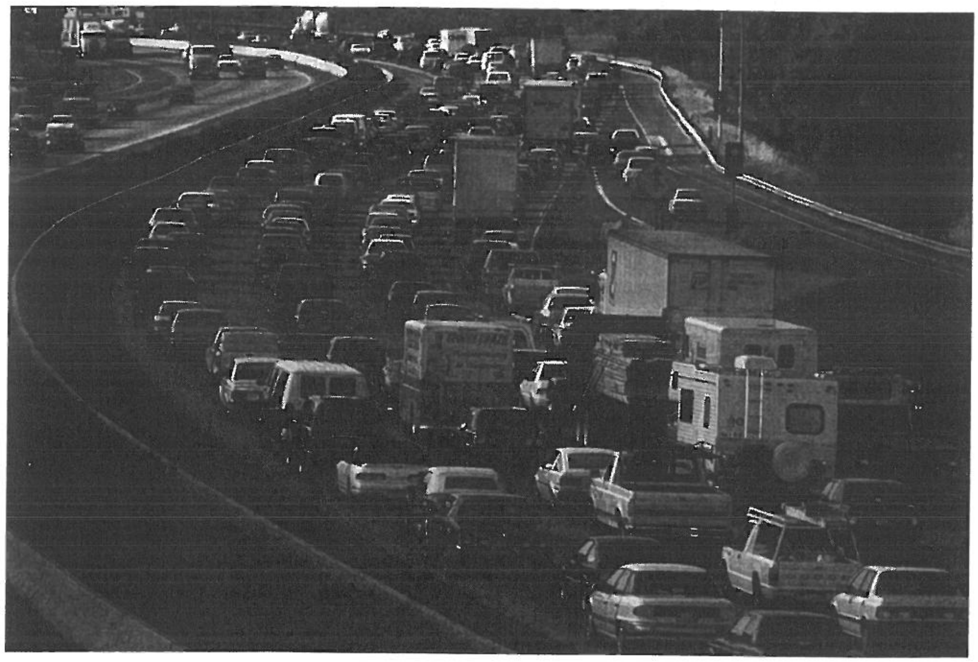
Chapter Four

Cost-Benefit Analysis



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Cost-benefit analysis is the measuring of the costs of a project and the benefits of a project to help decide whether to undertake the project and what the scale of the project should be. Consider these decisions facing government: Should a particular highway be built? Should improvements be made in a highway to make it safer? How much should carbon fuel use be cut (through a carbon tax or permits) to reduce global warming? Should Medicare pay for costly treatment X? Should a military intervention be undertaken? In these and many other decisions, economists recommend weighing cost against benefit to help guide the decision. In this chapter, using these examples, we examine how cost-benefit analysis can help us arrive at better decisions in the public sector.

The basic principle of cost-benefit analysis is simple:

A project should be undertaken if its benefit to society exceeds its cost to society. The scale of such a project should be increased as long as the marginal social benefit (MSB) exceeds the marginal social cost (MSC) so that the optimal scale occurs where MSB equals MSC.

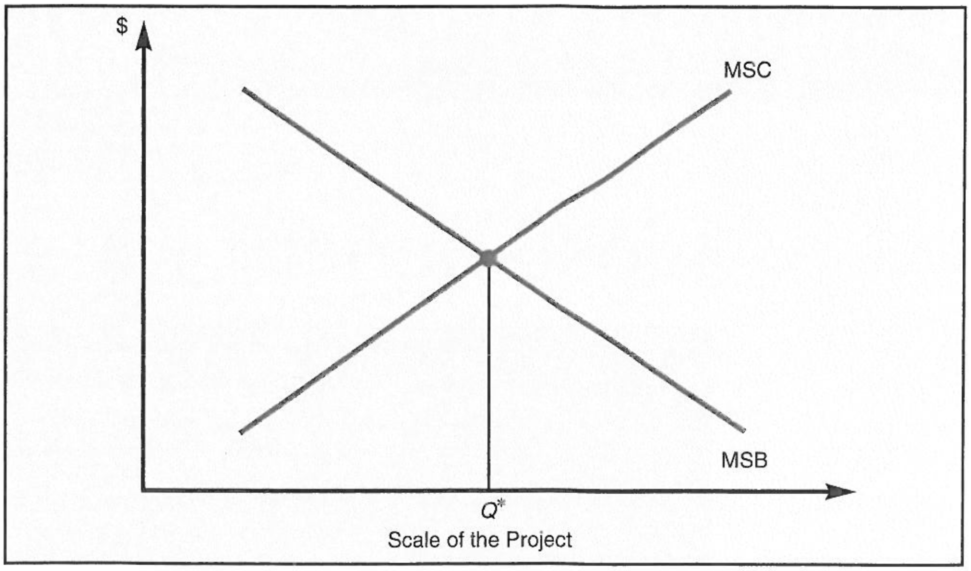

FIGURE 4.1
The Optimal Scale of an Investment Project
The scale where MSB equals MSC is socially optimal.

The optimal scale of an investment project is shown in Figure 4.1. At any scale of the project less than Q^*, the MSB exceeds the MSC so it is socially optimal to increase the scale another unit. At any scale of the project greater than Q^*, the MSB is less than the MSC so it is socially optimal to decrease the scale another unit. Hence, the optimal scale is Q^*. The challenge comes in measuring and comparing the marginal social benefit, which comes in the future, to the marginal social cost, which occurs in the present.

In discussing cost-benefit analysis, economists and others often drop the word *marginal* and simply say that an investment should be undertaken as long as the benefit exceeds the cost. We follow this convention by usually omitting the word *marginal.* Remember, however, that the question is not simply whether a project should be undertaken but also whether the scale (quantity or quality) of the project is optimal. Finding the optimal scale involves comparing the marginal benefit from raising the quantity or quality an *additional* (*marginal*) unit with the marginal cost of that additional unit.

Some noneconomists have criticized cost-benefit analysis because they believe it is unethical to weigh a benefit such as a life saved or a reduction in global warming against money—its cost. But cost, though measured in money, means **opportunity cost**—the benefit that could have been enjoyed by using the resources to produce other goods and services. Thus, cost-benefit analysis is a means of comparing the benefit from one project to the benefit people could have enjoyed by using the resources to make other goods or services.

COST-BENEFIT ANALYSIS

Private firms and individuals use cost-benefit analysis all the time. Firm managers compare the cost of a new factory or machine to its benefit: the increase in future profits. Individuals compare the cost of higher education or training to its benefit: the increase in future earnings. The principles of cost-benefit analysis therefore apply to firms, individuals, and government. Whoever is weighing cost against benefit faces essentially the same problem: measuring costs, measuring benefits, and recognizing the role of the interest rate in converting a future value to a "present value." When government uses cost-benefit analysis, measuring benefits is often difficult because the analyst must rely on imperfect methods, such as revealed preference and contingent valuation. We begin with an example in which a private firm weighs cost against benefit. We then consider several examples in which the government weighs cost against benefit.

A PRIVATE FIRM

Building a Factory

Consider a firm with expanding demand for its product. With its current factory the firm is already producing at capacity, so to take advantage of the expanding demand, the firm would have to build another factory. To decide whether it is worth building another factory, the firm must compare the cost of building the factory with the benefit—the additional profit that can be made by producing and selling more. In order to keep things as simple as possible, we assume there is no taxation.

Suppose that the factory would be built in one year (year 0) and that it will last only one year (year 1) before wearing out. The construction cost in year 0 would be \$100,000, and the profit (*excluding any interest cost due to borrowing*) in year 1 would be \$110,000. Should the firm build it? The answer depends on whether the interest rate at that time is greater or less than 10%.

Building with Borrowing

Suppose the firm must borrow \$100,000 in year 0 to pay for the construction cost, and will repay the loan in year 1. If the interest rate is 5%, the firm must repay \$105,000; the profit of \$110,000 would more than cover the loan repayment, and the correct decision is to build. However, if the interest rate is 15%, the firm must repay \$115,000; the profit of \$110,000 would not cover the loan repayment, and the correct decision is not to build.

Present Value

It is useful to consider an equivalent way of arriving at the decision. The \$100,000 cost occurs this year—in the present—but the \$110,000 profit occurs next year—in the future. Is the \$110,000 next year enough? We take the present value (PV) of the \$110,000 which equals \$110,000/$(1 + r)$ where r is the interest rate:

$$\text{PV of \$110,000 in year 1} = \frac{\$110{,}000}{(1 + r)}$$

If $r = 10\%$, the PV of \$110,000 in year 1 equals \$100,000 today in year 0.

The **present value (PV)** of a future amount at a future date is the amount you would need to put in the bank today to have that future amount by that future date.

In this example, you would have to put \$100,000 in the bank today (year 0) to have \$110,000 by next year (year 1). Clearly, present value depends on the interest rate.

Present value is sometimes called the *present discounted value* to emphasize the fact that it is obtained by dividing the future value by a number greater than 1—that is, discounting the future value. In particular, the future value is divided by (1 + the discount rate); in our example, the discount rate is the interest rate. We omit the word *discounted* and use the term *present value* and the abbreviation *PV*.

TABLE 4.1
Correct Decision Rule

	$r = 5\%$	$r = 15\%$
PV of profit	$104,762	$ 95,652
Cost of project	100,000	100,000
Correct decision	Build	Don't build

Taking the present value is the opposite of compounding. If you put $100,000 in the bank in year 0 and the interest rate r is 10%, it would compound to $110,000 in year 1. So having $110,000 in year 1 is equivalent to having $100,000 in year 0. Hence, with $r = 10\%$, the PV of $110,000 in year 1 is $100,000.

If $r = 5\%$, the PV of $110,000 equals $104,762; and if $r = 15\%$, the PV of $110,000 equals $95,652. This leads us to the correct decision rule shown in Table 4.1: Build the factory if the PV of the future profit, $110,000, is greater than the cost, $100,000; don't build the factory if the PV of the profit is less than the cost.

Building without Borrowing

Suppose the firm has the cash from past profits to build another factory without borrowing. The decision to build *still* depends on whether the interest rate is greater or less than 10%—equivalently, on whether the PV of the profit exceeds the cost ($100,000). At first glance, it might seem that without borrowing, the interest rate is irrelevant, but this is not so. If the firm doesn't build the factory, it can keep its $100,000 in the bank so that it earns interest. If $r = 5\%$, the bank account would grow to $105,000 next year, so it would be better to build the factory and earn a profit of $110,000 next year. However, if $r = 15\%$, the bank account would grow to $115,000 next year, so it would be better not to build the factory.

Thus, whether or not the firm must borrow, it remains true that the correct decision is to build the factory if and only if the PV of the profit (computed using the actual interest rate) exceeds the cost. The numbers in Table 4.1 remain relevant. If $r = 5\%$, the PV of the profit will be $104,762 so the factory should be built. If $r = 15\%$, the PV of the profit will be $95,652 so the factory shouldn't be built.

Multiyear Profits

Now suppose that the factory lasts two years instead of one. Profit is $55,000 in year 1 and $60,500 in year 2. Then the present value of profits over the two years is

$$\text{PV of profits} = \left[\frac{\$55{,}000}{(1+r)}\right] + \left[\frac{\$60{,}500}{(1+r)^2}\right]$$

where r is the interest rate. Note that the year 1 profit is divided by $(1 + r)$ but the year 2 profit is divided by $(1 + r)^2$. Note also that if there were a year 3 profit, it would be divided by $(1 + r)^3$. If r is 10%, then:

$$\text{PV of profits} = \left(\frac{\$55{,}000}{1.10}\right) + \left(\frac{\$60{,}500}{1.10^2}\right) = \$50{,}000 + \$50{,}000 = \$100{,}000$$

If r is less than 10%, the PV of the profits will be greater than the cost ($100,000), and the factory should be built. If r is greater than 10%, the PV of the profits will be less than the cost ($100,000), and the factory should not be built. Thus, the correct decision rule remains the same: Build the factory if the PV of future profits is greater than the cost; don't build the factory if the PV of profits is less than the cost.

REDUCING GLOBAL WARMING

Cost-benefit analysis can also be applied to a broader issue like global warming. How much should each country cut back on its emission of greenhouse gases such as carbon dioxide in an effort to combat global warming? Cutting back is costly—carbon fuel combustion must be reduced, thereby reducing driving and goods that are produced using fuel. Assume such a cutback is likely to reduce global warming in the future. Such a reduction in warming would benefit many (though not all) countries. Cutting back should occur as long as the marginal cost of further cutback is less than the marginal benefit of further reduction in future warming.

Suppose a carbon tax is the method used to induce the cutback. If the tax is $50 per ton, then it will be profitable for fuel producers to cut back as long as the marginal cost of cutback is less than $50 and to stop when the marginal cost reaches $50. This must be compared to the marginal benefit resulting from that last unit of cutback. If the marginal benefit is greater than $50, then the tax should be raised to induce more cutback. The tax should be adjusted until the marginal cost equals the marginal benefit.

The benefit occurs in the future when there would be less warming as a consequence of less emission today. Suppose it is estimated that the additional future warming from another ton emitted today would reduce crops by $*X*, raise air-conditioning by $*Y*, and flood coastal property worth $*Z*. If these total $50, current cutback is optimal; if they total more than $50, further cutback is optimal; and if they total less than $50, less cutback is optimal.

Uncertainty and the Risk of Catastrophe

Suppose there is a small chance that failure to reduce global warming will lead to catastrophe—enormous values for $X, $Y, and $Z. Then it is unsatisfactory simply to use the most likely values of $X, $Y, and $Z and compare them to the cost of reducing global warming. The analysis should incorporate the possibility that the future benefit of reducing global warming will be huge—avoiding a catastrophe.

One way to incorporate the possibility of catastrophe is to use a weighted average of the most likely values and the catastrophic values of $*X*, $*Y*, and $*Z*, where the weights for the catastrophic values equal the estimated probability of occurrence. Of course, the probability can only be estimated, not known with certainty, but some adjustment is surely better than simply ignoring the possibility of catastrophe in weighing cost against benefit to arrive at a decision.

The Social Discount Rate

To compare today's cost to tomorrow's benefit, analysts must discount the future benefit to obtain the present value. They must determine what should be the **social discount rate**—the rate analysts use to compute the present value of future benefits. The higher the social discount rate, the lower the PV of future benefits, and the less likely that the marginal benefit will exceed the marginal cost for the proposed government policy.

For a business firm seeking profit, the market interest rate at which the firm can actually borrow is utilized as the discount rate. For a government that is building or improving a highway, the market interest rate at which the government can actually borrow is also generally utilized as the proper discount rate. In both cases, the market interest rate indicates what could have been generated by the funds through alternative investments if the funds were not used by the firm or the government.

For a very long-term problem that spans generations, like global warming, there is less of a consensus about whether the market interest rate is the appropriate discount rate. Some economists contend that because the central issue is the trade-off between the well-being of different generations (rather than the same generation at different ages in its life cycle), the social discount rate—the rate the government should use for a cost-benefit evaluation of a long-term policy—should be lower than the actual market interest rate at which the government can borrow.

Other economists favor using the market interest rate. They argue that if a particular policy fails the cost-benefit test using a market interest rate, this means that the policy is not the best way for the current generation to help a future generation. Instead, the current generation should use the funds to save and invest productively for the future, earning a return equal to the market interest rate. Rather than cut back today's output to cut back carbon, the current generation should save and invest more, leaving future generations with a higher capital stock to compensate for the warming. For an example of the importance of the discount rate, see the box "The Debate over the 2006 Stern Review on Global Warming."

Current Research The Debate over the 2006 Stern Review on Global Warming

In November 2006, a comprehensive report on global warming was released in Britain with the endorsement of then Prime Minister Tony Blair. The report's primary author was the economist Nicholas Stern, and the report was called *The Stern Review on the Economics of Climate Change*. The *Stern Review* estimated that a failure to sharply and promptly reduce greenhouse gas emissions to a particular target would cause damage equal to 5% of GDP per year. Hence, the benefit of reducing emissions from the projected level under business as usual to the Stern target would be 5% of global GDP per year. The *Stern Review* estimated that the cost of this sharp and prompt emissions reduction would be only 1% of global GDP per year.

In his 2007 review of the *Stern Review*, economist William Nordhaus of Yale University,* who has constructed empirical economic models of global warming, reports that his most recent model, also based on cost-benefit analysis, prescribes a much more moderate gradual "ramping up" of emissions reduction than the *Stern Review*. Nordhaus's model prescribes a carbon tax today of $17 per ton, while the *Stern Review* prescribes a carbon tax today of $311 per ton.

According to Nordhaus, the main reason for the huge difference in their policy recommendations is the choice of the value for the social discount rate. In his review, Nordhaus says that the *Stern Review* uses a near-zero social discount rate, so that benefits that occur in the far future from reducing global warming are given the same weight as costs that occur in the present. Nordhaus says that if the *Stern Review* had used the standard positive social discount rate used in most cost-benefit studies (roughly 3%), which gives much less weight to benefits in the far future than costs in the present, its prescription would have been similar to his model's prescription. Nordhaus runs his economic model first with his standard social discount rate of 3% and then with the *Stern Review's* 0.1% discount rate. He finds that with his discount rate a carbon tax of $17 per ton should be imposed today rising gradually to $84 in 2050 and $270 in 2100, so that the optimal rate of emissions reduction is 6% today, 14% in 2050, and 25% in 2100. But when he runs his model with the *Stern Review's* near-zero discount rate (0.1%), he finds that his model would then prescribe the optimal carbon tax today to be $159 (instead of $17), and optimal emissions reduction in 2015 would be 50%. The *Stern Review* itself prescribes a carbon tax today of $311, so the discount rate is not the sole reason for the huge difference, but it is clearly a key reason for the difference.

Another reason for the difference is the way the two models compare persons with different levels of consumption. If productivity continues to advance with technological progress, then people in the future will enjoy much higher per capita consumption than people today. Emissions reduction today to reduce global warming tomorrow means sacrificing consumption by people today in order to prevent a sacrifice in consumption by people in the future. However, people in the future will be able to "afford" a sacrifice in consumption more than people today, because they will be starting from a much higher level of consumption due to technological progress. Nordhaus says that the *Stern Review* does not sufficiently recognize this difference.

How can we decide which social discount rate and which comparison of persons with different levels of consumption are the proper ones to use in a cost-benefit analysis of global warming? Nordhaus offers one way. He says to look at the actual saving rate of most economies. Saving is the main way that people sacrifice today in order to benefit in the future. Nordhaus argues that the actual saving rate reveals how much people value future consumption relative to present consumption and how they compare a sacrifice starting from different levels of consumption. He says that the values he uses in his model generate a saving rate for the economy that corresponds to the actual saving rate observed, while the *Stern Review's* values imply a saving rate much higher than we observe.

* William D. Nordhaus, "A Review of the *Stern Review on the Economics of Climate Change*," *Journal of Economic Literature* 45, no. 3 (September 2007), pp. 686–702.