An Overview of Benefit-Cost Analysis

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Part 1 -- Benefit-Cost Analysis

1.1 What is benefit-cost analysis?

Benefit-cost analysis (BCA) is a technique for evaluating a project or investment by comparing the economic benefits with the economic costs of the activity. Benefit-cost analysis has several objectives. First, BCA can be used to evaluate the economic merit of a project. Second the results from a series of benefit-cost analyses can be used to compare competing projects. BCA can be used to assess business decisions, to examine the worth of public investments, or to assess the wisdom of using natural resources or altering environmental conditions. Ultimately, BCA aims to examine potential actions with the objective of increasing social welfare.

Regardless of the aim, all benefit-cost analyses have several properties in common. A BCA begins with a problem to be solved. For example, a community may have the goal of alleviating congestion on roads in an area. Various projects that might solve the particular problem are then identified. As an example, alternative projects to alleviate road congestion in an area might include a new highway, a public bus system, or a light rail system. The costs and benefits of these projects would be identified, calculated, and compared. Decisions are typically not made solely on the basis of BCA, but BCA is useful and sometimes required by law. Without a doubt, results from a BCA can be used to raise the level of public debate surrounding a project.

1.2 BCA examples

Explicitly or implicitly, nearly every public and private decision involves some comparison of benefits and costs. Although a formal BCA is not used for all decision making, the principles are applied in many settings. Here are a few brief examples.

Example 1: You must decide whether to go out with your friends to a local "watering hole" on a Thursday night. Going out will have associated benefits and costs. The benefits include spending time with your friends and receiving free drinks from the bartender (who happens to be your best friend). The costs of the night include (at minimum) a cab ride home, missing class the next day (and possibly missing a surprise quiz), and waking up with a nasty hangover. Costs could run higher.

Example 2: Society must decide whether to open-up an old-growth forest for logging. Logging would provide a variety of benefits, but will also entail costs. The products and employment generated by logging are benefits. Some of the costs of cutting the old-growth forest include the cost of cutting, the loss of wildlife habitat, damages to local streams due to runoff, and the loss of an opportunity to cut the forest sometime in the future.

Example 3: An agency must decide whether to impose regulations to conserve a biologically important wetland. Conserving the wetland has environmental benefits. The wetland provides habitat for a variety of animals, including waterfowl. The wetland ultimately provides benefits to hunters and bird-watchers. The wetland also provides benefits because it helps to maintain water quality and reduces flooding in neighboring areas. However, land that would be conserved could be used in a different way, say for agriculture or a shopping mall. This loss in use is an opportunity cost. Landowners may also incur some direct costs in protecting wetlands on their property or some opportunity costs associated with not using these areas in another way. BCA can be used to compare the benefits and costs of imposing the regulation.

1.3 BCA in a timeless world

We now consider an example of BCA in greater depth. Suppose society is considering the construction of a large dam. The dam and resulting reservoir will provide numerous benefits and entail many types of costs. Here we simplify the story for the sake of our example. First consider the cost of building the dam. We assume the cost of construction is $500,000 for materials and $600,000 for labor. Now consider the benefits. Once the dam has been built, people will be able to go swimming, boating, and fishing in the reservoir. The total value of these recreational benefits is $400,000. The dam is also expected to provide flood control benefits for downstream residents. The saving due to this flood control is estimated as $300,000 in reduced damages to homeowners or farmers. The dam also produces electricity valued at $500,000. Since the total benefits are $1,200,000 and the total costs are $1,100,000, the benefits exceed the costs and dam construction appears to be a good investment. Benefit-cost analysis has been used to compare the benefits and costs of the project.

However, to know whether society should actually build the dam, other information is needed. For example, it will be necessary to compare the dam project with other possible uses of the funds. It might be the case that a $1.1 million investment in education could lead to more than $1.2 million in benefits. If so, the dam might be a good use of society's resources, but perhaps not the best use of those resources.

1.4 Time and discounting

The example used above ignores the issue of time. In comparing the benefits and costs of the dam we didn't really consider when those benefits and costs occurred. But in many cases the timing of benefits and costs is an important aspect of the project under consideration. For this reason, dealing adequately with the timing of benefits and costs becomes a crucial part of the BCA. For example, what if the cost of constructing the dam is incurred this year, but the benefits of using the dam are not felt until next year, after the dam is completed. In this case will next year's benefits outweigh this year's costs? To deal with this kind of question, benefit-cost analysis uses a concept known as discounting.

Discounting is a technique that converts all benefits and costs into their value in the present. Discounting is based on the premise that a dollar received today is worth more than a dollar received in the future. This bias toward the present arises because by placing a dollar in a safe investment today, you can increase its value to more than a dollar tomorrow. Another way of saying this is that a dollar received in the future is not worth as much as that same dollar received in the present. That is, the future value of the dollar is discounted. Discounting is the opposite of compounding. Not surprisingly, the rate at which a future value is discounted is closely related to the rate at which present values are compounded, namely the interest rate. As we know from compounding, if the interest rate is 5%, then a dollar placed in the bank today will be worth $1.05 a year from now. This means that if the interest rate is 5%, $1.05 to be received next year is worth only $1.00 today.

Whenever the benefits and costs used in a benefit-cost analysis occur in the future, it is important to discount these future values to account for their present value. If the interest rate is r, then the following formula can be used to find the present value (PV) of an amount (P_t) received at some time t in the future:

$$PV = \frac{P_t}{(1+r)^t}$$

To apply the formula, remember:

PV is the present value of the amount invested;
P_t is the dollar value of the future amount in time *t*;
r is the discount rate; and
t is the year in which P_t is realized.

For example, suppose that in the example of the dam construction cited above the cost of dam construction ($1.1 million) is incurred at the beginning of the project (*t*=0), but the benefits ($1.2 million) arise one year later, after the dam is finished (*t*=1). Suppose the interest rate is 10%.

The present value of the benefits are:

$$Benefits = \frac{\$1{,}200{,}000}{(1+0.10)^1} = \$1{,}090{,}909$$

The present value of the costs are:

$$Costs = \frac{\$1{,}100{,}000}{(1+0.10)^0} = \$1{,}100{,}000$$

After the correction for the timing of benefits and costs (that is, on a *present value* basis), the benefits of the dam no longer exceed the costs of the dam and the dam looks like a less worthwhile investment. The reason for the change is that the discount rate now reduces the value of benefits because they occur in the future.

As another example, suppose you are given the choice of two investments. The first pays you $210 today, but nothing thereafter. The second investment pays $100 today, and $115 next year (for a total of $215). The second investment looks better, right? Maybe or maybe not. It depends on the discount rate. If the discount rate is 5%, which is the better investment? We find out by applying the present value formula:

PV of investment 1:

$$= \frac{\$210}{(1+.05)^0} + \frac{\$0}{(1+.05)^1} = \$210$$

PV of investment 2:

$$= \frac{\$100}{(1+.05)^0} + \frac{\$115}{(1+.05)^1} = \$209.5$$

Even though the second investment pays out a greater sum, after discounting the first deal looks like a better choice.

This basic formula for discounting can be applied regardless of the length of the time horizon.

There is no simple rule for choosing a discount rate. One method is to use the opportunity cost of capital as the discount rate. The opportunity cost of capital is the return that would be received if the funds being invested were invested in the private sector (say in a business or in the bond market). Often the discount rate is simply set equal to a well-publicized interest rate. For example, the cost to the federal government of borrowing can be used as a discount rate. The discount rate could also be derived from what is called the social rate of time preference (SRTP). The SRTP attempts to compensate for the fact that people prefer to consume now rather than later. Because of this preference, individuals might have a bias in favor of projects that have benefits sooner rather than later. For some projects, society may want to take a longer-range perspective than individuals or businesses, and the SRTP tries to make this adjustment. For example, do you think construction of the Washington Monument would have passed a benefit cost analysis if people had a high preference for projects with immediate benefits?

Part 2 -- Benefit-Cost Measures

2.1 BCA measures

Several variations on the basic benefit-cost rule can be used to compare the benefits and costs of investments, projects, or decisions.

2.1.1 Net present value (NPV)

The net present value (NPV) is the current value of all project net benefits. Net benefits are simply the sum of benefits minus costs. The sum is discounted at the discount rate. Using this method, if the project has a NPV greater than zero then it appears to be a good candidate for implementation. The formula used to calculate the NPV is:

$$NPV = \sum_{t=1}^{T} \frac{\left(Benefit_t - Cost_t\right)}{(1+r)^t}.$$

2.1.2 Benefit-cost ratio (BCR)

The benefit-cost ratio (BCR) is calculated as the NPV of benefits divided by the NPV of costs:

$$BCR = \frac{\sum_{t=1}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{T} \frac{C_t}{(1+r)^t}}$$

where $B_t$is the benefit in time *t* and $C_t$is the cost in time *t*. If the BCR exceeds one, then the project might be a good candidate for acceptance.

2.1.3 Internal rate of return (IRR)

The internal rate of return (IRR) is the maximum interest that could be paid for the project resources, leaving enough money to cover investment and operating costs, which would still allow the investor to break even. In other words, the IRR is the discount rate for which the present value of total benefits equals the present value of total costs:

$$PV(Benefits) - PV(Costs) = 0.$$

In general, the IRR should be greater than the discount rate for a project to be accepted.

2.2 Advantages and disadvantages of using benefit-cost analysis

BCA is a valuable tool for decision making. It is most useful because it provides a starting point from which to begin evaluation of a project. BCA forces project advocates and opponents to provide quantitative data to back up qualitative arguments. With BCA actual data must be used to support the analysis. Typically, some subjective reasoning or value judgments come into play when deciding on projects or investments. While BCA may not be able to include all the criteria which is deemed important in evaluation, it does allow interested parties to clearly define the issues involved.

BCA is also useful because it allows comparisons to be made between investments or projects. This comparison is made easier because all investments are evaluated using the same method. It then becomes easier to exclude obviously bad projects from consideration.

While BCA can be useful, there are some difficulties with its application. First, it requires that the analyst assign monetary values to all benefits and costs. As we know, however, there are numerous benefits and costs which are intangible and therefore difficult to value. For projects with an environmental impact, for example, it can be difficult to place a dollar value on the benefits and costs. While the value of timber may be easy to calculate, the value of a spotted owl may not.

Another drawback with BCA is the fact that results can be very sensitive to the choice of the discount rate. The entire result from a complex BCA may hinge on the choice of a single number for the discount rate. For this reason, BCA can be very controversial. The rate that is chosen can radically change the outcome of analysis (to convince yourself of this, try re-working the examples above using different discount rates).

Finally, an important drawback with BCA is that while most benefits and costs that arise in the present are known, many that arise in the future are unknown. A BCA must be conducted using information that is available. This information will be limited by our current knowledge of benefits and costs. Some future benefits and costs cannot conceived, much less measured. However, the role of uncertainty plagues not only BCA but also most other decision-making methods.

2.3 Intergenerational equity

As stated earlier, it is commonly the case that people prefer consumption in the present to consumption in the future (you only have to consider how many people have credit card debt to convince yourself of this!). However, this preference for current consumption has some interesting and important implications regarding intergenerational equity.

People in the current generation would prefer to consume resources now. Those in later generations would rather have access to these resources during their lifetimes (which have not yet started). The problem is that these future generations do not have a say in the decisions made today. Investments or projects may be chosen that benefit the current generation, but decrease the amount of resources available to future generations.

The philosopher John Rawls proposed a method by which issues such as equity between generations might be solved. In Rawls’s plan, members of the present generation would be hypothetically and temporarily stripped of their generational standing. All individuals would then work together to choose investments or projects. All decisions would be made from behind this "veil of ignorance." In other words, an individual would know how any particular decision affected each generation, but he or she would not know how a decision affected his or her own specific generation (since no one knows to which generation he will belong). After all decisions have been made, each person is then assigned to live either in the present or the future. Ideally, if a person votes without knowing to which generation he or she will ultimately be assigned, he or she will have no incentive to prefer one generation to another. That is, the final investment decision made using this procedure should not be biased in favor of a particular generation because each decision-maker could potentially become the member of any generation. Future generations are then given a voice while not depriving those in the present of their voice. Following a similar logic, some people have argued that when important public decisions are to be made, one person should be assigned to be a spokesperson for future generations.

2.4 Dam construction example revisited

Having now examined the range of issues encountered in benefit-cost analysis in somewhat greater depth, let us reconsider the example of dam construction. This time, we will examine the benefits and costs in greater detail. To begin, we now assume that construction of the dam will take two years. The cost of construction is the same as before ($1.1 million) but now the construction costs are equally spread over two years ($550,000 in year 1 and $550,000 in year 2). We also assume that the dam has an operating life of 18 years. The entire project, therefore, spans 20 years. To simplify matters we assume that there is no inflation during the entire life of the project, and that all benefits and costs are known with certainty (strong assumptions!). Unlike before, we now assume that during the 18 years of dam operation the structure must be maintained at some cost. These operating costs are $50,000 per year. As for benefits, the dam project will produce 5,000,000 KWH of electricity each year (after construction) at a cost of $0.05 KWH. This cost represents a savings of $0.02 per KWH over the next best method of electricity generation. These savings in electricity cost constitute a benefit. The dam will also produce a reservoir for recreation. We assume that there will be 50,000 person days per year of recreation benefits and that the value of these recreation benefits is $1.00 per person per day. We want to know whether construction of the dam is a worthwhile project.

To analyze this example Table 1 presents the benefits and costs for the dam in tabular form. Combined with a discount rate, these data can be used to calculate the NPV and the BCR. These data can also be used to calculate the IRR. Results of these calculations are presented in Table 2.

Note that the NPV and BCR measures both point to the same conclusion. At a discount rate of 10%, the dam should not be built (costs exceed benefits). However, at a lower discount rate of 5%, the project looks like a good investment. Specifically, at any discount rate less than 5.5% (the IRR) the benefits of the project exceed the costs.

Table 1. Benefits and costs for dam

Year	Construction Costs	Operating Costs	Recreation Benefits	Electricity Benefits	Total Benefits	Total Costs	Net Benefit
1	550,000	0	0	0	0	550,000	-550,000
2	550,000	0	0	0	0	550,000	-550,000
3	0	50,000	50,000	100,000	150,000	50,000	100,000
4	0	50,000	50,000	100,000	150,000	50,000	100,000
5	0	50,000	50,000	100,000	150,000	50,000	100,000
6	0	50,000	50,000	100,000	150,000	50,000	100,000
7	0	50,000	50,000	100,000	150,000	50,000	100,000
8	0	50,000	50,000	100,000	150,000	50,000	100,000
9	0	50,000	50,000	100,000	150,000	50,000	100,000
10	0	50,000	50,000	100,000	150,000	50,000	100,000
11	0	50,000	50,000	100,000	150,000	50,000	100,000
12	0	50,000	50,000	100,000	150,000	50,000	100,000
13	0	50,000	50,000	100,000	150,000	50,000	100,000
14	0	50,000	50,000	100,000	150,000	50,000	100,000
15	0	50,000	50,000	100,000	150,000	50,000	100,000
16	0	50,000	50,000	100,000	150,000	50,000	100,000
17	0	50,000	50,000	100,000	150,000	50,000	100,000
18	0	50,000	50,000	100,000	150,000	50,000	100,000
19	0	50,000	50,000	100,000	150,000	50,000	100,000
20	0	50,000	50,000	100,000	150,000	50,000	100,000

Table 2. BCA decision criteria

	Discount rate	
	10%	**5%**
NPV (want NPV > 0)	-509,355	39,485
BCR (want ratio > 1)	0.786	1.024
IRR (want IRR > discount rate)	5.4%	

Further Reading on Benefit-Cost Analysis

General Overview

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