

Lecture # 24 – Cost-Benefit Analysis

I. Steps to Cost-Benefit Analysis (continued)

4. Discounting

- The costs and benefits will occur at different times. To compare them fairly, it is important to discount costs and benefits that occur in the future.
 - The idea is to compare a flow of benefits and costs into a single value.
- The present value of a future amount of money is the maximum amount you would be willing to pay today for the right to receive that money in the future.
 - Present value accounts for the opportunity cost of not investing the money elsewhere.
 - Example:
 - You have \$100 now
 - If you put it in the bank, you will get 5% interest
 - Next year, that money is worth $(1 + 0.05) \times 100 = \105
 - After two years, it is worth $(1.05)(1.05)(100) = (1.05)^2(100) = \110.25
 - General rule:
 - $PV = \text{present value (the principal that you invest)}$ $r = \text{interest rate}$
 - $\text{Future Value} = FV = PV(1 + r)^t$
 - As a result, you wouldn't give up \$100 now for \$100 next year, because you could invest the money and get \$105 next year.
 - The present value of \$100 next year is the most you would give up today to get \$100 next year
 - $FV = \$100 = PV(1.05) = \100
 - $PV = 100/1.05 = \$95.24$
 - General rule
 - $PV = FV/(1 + r)^t$
 - For a stream of payments:
 - $PV = FV + FV/(1+r) + FV/(1+r)^2 + \dots + FV/(1+r)^t$
 - For payments forever:
 - $PV = FV/r$
- In these examples, r represents the discount rate. The discount rate reflects the relative value a person places on future consumption compared to current consumption.
 - Lower values show a greater preference for future consumption.
 - A high discount rate says that current consumption is important to you.
 - A low discount rate says that future consumption is important to you.

- What about inflation?
 - When we are discounting costs & benefits, we must remember that inflation affects the interpretation.
 - The key is to be consistent.
 - If all the dollar values are real dollars – already adjusted for inflation – use a real rate of interest.
 - If all the dollar values are nominal dollars – we need to adjust for inflation. We use a nominal rate of interest.
 - Recall our example from before. Suppose inflation is 3%. Then, \$105 next year is only worth $105/1.03 = \$101.94$ today.
 - The present value now is $100(1 + r) = \$101.94$
 - This implies a rate of return of approximately 2%.
 - *Inflation lowers the real return on our investment.*
 - For those interested in the derivation of the real rate of return, define the following terms:
 - r = real rate of interest
 - γ = rate of inflation
 - m = nominal rate of interest
 - the nominal return $(1 + m) = (1 + r)(1 + \gamma) = 1 + r + r\gamma + \gamma$
 - $\Rightarrow m = r + r\gamma + \gamma$
 - or $r = (m - \gamma)/(1 + \gamma)$
 - In practice, $r\gamma$ is very small, so a useful approximation is:
 - $m = r + \gamma$ or
 - $r = m - \gamma$
 - E.g. nominal rate = 5%, inflation = 3% \Rightarrow real rate = 2%
 - Key point: if nominal prices are used, discount using a nominal rate of interest, so that inflation is accounted for. If real prices are used, inflation has already considered. A nominal rate would double count inflation. Therefore, use a real rate of interest.
 - In general, the real rate of interest will be around 3-5%. In the next class we will discuss more carefully how to select the discount rate.
- What about capital?
 - Since we are discounting, the cost of capital should be included in the year the capital is purchased.
 - Depreciation is not necessary. The full cost is already considered when the cost of purchasing the capital is recorded. Adding depreciation would lead to double counting.
 - However, if the capital is not completely used, the salvage value should be added as a benefit at the end of the program.

5. Interpreting the Results

- Once our calculations are complete, how do we interpret the final results? There are several alternative criteria.

1. Net present value (NPV) – the present value of benefits minus the present value of costs

- If NPV is positive, the project is worth doing.
- If several projects are under consideration, choose the one with the highest NPV.
- Advantage: not sensitive to whether something is recorded as a cost or a benefit.
- Example:
 - Consider two projects: both have costs in first year, followed by annual benefits received forever
 - Discount rate = 5%

A			B		
Year	Benefit	Cost	Year	Benefit	Cost
0	\$0	\$1000	0	\$0	\$100
1+	\$100	\$0	1+	\$20	\$0

$$NPV_A = 0 - \$1,000 + \frac{\$100 - 0}{0.05} = -\$1,000 + \$2,000 = \$1,000$$

$$NPV_B = 0 - \$100 + \frac{\$20 - 0}{0.05} = -\$100 + \$400 = \$300$$

- Project A has the higher NPV

2. Internal Rate of Return – the discount rate that would make a project's net present value equal zero.

- A project is worthwhile if the IRR is greater than the opportunity cost of funds for the community (that is, the appropriate discount rate).
- Problem: Doesn't account for the size of the project
- Continue with the example from above

$$\begin{aligned} IRR_A: -\$1,000 + \$100/r &= 0 \\ \$100/r &= \$1,000 \\ \$100/\$1,000 &= r \\ r &= 0.1 \end{aligned}$$

$$\begin{aligned} IRR_B: -\$100 + \$20/r &= 0 \\ \$20/r &= \$100 \\ \$20/\$100 &= r \\ r &= 0.2 \end{aligned}$$

- Although project A has a higher net present value, project B has a higher internal rate of return.

3. Benefit –cost ratio – the ratio of the present value of a stream of benefits to the present value of the stream of costs.

- A project is acceptable if BC ratio > 1.
- Problems
 - Does not take the scale of the project into account.
 - Continue with the example from above
 - Project A: \$2,000/\$1,000 = 2
 - Project B: \$400/\$100 = 4
 - Although project A has a higher net present value, project B has a higher benefit-cost ratio.
 - More importantly, benefit-cost ratios are sensitive to whether items are recorded as costs or benefits.
 - Example:

A			B		
Year	Benefit	Cost	Year	Benefit	Cost
0	\$0	\$35,000	0	\$40,000	\$0
1	\$40,000	\$0	1	\$0	\$40,000

$$NPV_A = 0 - \$35,000 + \frac{\$40,000 - 0}{1.05} = -\$35,000 + \$38,095.24 = \$3,095.24$$

$$NPV_B = \$40,000 - 0 + \frac{\$0 - \$40,000}{1.05} = \$40,000 - \$38,095.24 = \$1,904.76$$

- Project A has the higher NPV
- Project A also has the highest benefit-cost ratio
 - A: B = \$40,000/1.05 = \$38,095.24
 - C = \$35,000
 - B/C = 1.088
 - B: B = \$40,000
 - C = \$40,000/1.05 = \$38,095.24
 - B/C = 1.05
- Now redefine the costs and benefits. Suppose we consider part of project B's benefit a negative cost instead (e.g. a cost savings):

A			B		
Year	Benefit	Cost	Year	Benefit	Cost
0	\$0	\$35,000	0	\$10,000	-\$30,000
1	\$40,000	\$0	1	\$0	\$40,000

- The NPV remains the same. There is still a \$40,000 net benefit in year 0.
- Recalculate the benefit-cost ratio for project B
 - B: B = \$10,000
 - C = -30,000 + \$40,000/1.05 = \$8,095.24
 - B/C = 10,000/8,095.24 = 1.24
- Now project B looks better. ***Simply changing how we define benefits and costs changes the interpretation of the benefit-cost ratio.***

- As a result of all of this, NPV is the best method to use.

- The interpretation of net present value (NPV) depends on the situation. Key questions:
 1. Are there several projects being considered?
 - If not, the project is acceptable if the NPV is positive.
 - If there are several alternative projects, choose the one with the highest NPV.
 2. Does the community budget limit the size of the project?
 - If so, choose the combination of projects that maximize net benefits, given the community's budget constraints.
 - Example:

	<i>Benefits</i>	<i>Costs</i>	<i>Net Benefits</i>	<i>Benefits/Costs</i>
<i>Project A</i>	10	1	9	10
<i>Project B</i>	22	10	12	2.2
<i>Project C</i>	8	4	4	2
<i>Project D</i>	4	2	2	2
<i>Project E</i>	8	10	-2	0.8

- In this case, if there is no constraint, choose A, B, C & D
- If there is a constraint, find the best combination
 - For example, consider a \$10 budget
 - Choosing A, C, & D give a net benefit of \$15, whereas B alone only gives net benefit of \$12.
- A note on the benefit-cost ratio
 - This is an example of how the benefit/cost ratio doesn't select the project with the highest NPV.
 - NPV is highest for B, but the benefit/cost ratio is highest for A.
 - However, when we face a budget constraint, the benefit/cost ratio helps us identify the project that has the most "bang for the buck."
- 3. Can the scale of the project be varied?
 - If so, choose the size where marginal benefits = marginal costs.

***** THE FOLLOWING NOTES DISCUSS THE LAST STEPS OF COST-BENEFIT ANALYSIS. WHILE WE MAY NOT HAVE TIME TO COVER THESE IN CLASS, I INCLUDE THEM HERE FOR COMPLETENESS ******

6. Equity Considerations

- So far, we have said nothing about the distribution of benefits. Of course, these are important, especially in the political arena.
- Transfer payments are shifts of resources from one group to another that do not involve a net change in the value of resources available to society as a whole.
 - Since there is no net change in the value to society, no resources are used, and no new value is created.
 - However, all of the transfers that we have discussed have important equity considerations.
 - A project that passes whose benefits exceed the costs may nonetheless be rejected if the distribution of benefits and costs is seen as unfair.
 - Examples of transfer payments:
 - Taxes paid (such as the emissions fees we discussed with externalities).
 - Unemployment benefits
 - Benefits provided to specific groups (e.g. welfare payments)
- Two principles for identifying and measuring transfer payments:
 - At the level of particular groups, transfer payments resemble conventional benefits and costs.
 - That is, resources they are willing to pay to acquire, or resources expended by the group represent a loss of opportunity value to the group.
 - However, for society as a whole, the sum of transfer payments to particular groups must sum to zero.
 - Since no value is created or destroyed, one group's benefit is another group's cost.
 - Transfer payments merely represent shifts of resources.
 - For example, secondary benefits are often offset by secondary costs.
 - Higher land values near the expanded DestinyUSA would be offset by lower demand for land in other locations, such as shopping areas on Erie Blvd.

- How can we deal with distributional issues in cost-benefit analysis?
 - All of the transfers that we have discussed have important equity considerations.
 - A project that passes whose benefits exceed the costs may nonetheless be rejected if the distribution of benefits and costs is seen as unfair.
 - However, we cannot put a dollar value on the changes in distribution.
 - Rather, the goal is to assess the changes, and then ask whether these changes are acceptable, or if they alter our perception of the program.
 - If possible, the benefits and costs falling on each group can be quantified.
 - However, even if this is not possible, judgments can be made.
- Guidelines for defining groups
 - Groups should not overlap, and should add up to comprise the total society affected by the program.
 - Overlapping groups lead to double counting costs and benefits.
 - The sum of transfer payments across groups should be zero.

7. Sensitivity Analysis

- CBA analyses always include assumptions. Examples of assumptions include:
 - What are the benefits of the project?
 - What are the costs?
 - For example, are some costs, such as pollution, unmeasured?
 - What discount rate should be used?
- As a result, sensitivity analysis is important.
 - You should show how the results change if key assumptions are varied.
- How to analyze sensitivity to key assumptions:
 - Determine a range of plausible values for uncertain costs or benefits.
 - Re-estimate the project's value using the highest and lowest values in the range.
 - Do the conclusions change?
 - Is NPV positive for some values, but negative for others?
 - Presenting results for different discount rates is also a good idea.
 - Summarize the results and compare them with the original results using the most likely assumptions.
 - Where possible, indicate the likelihood that the cost or benefit will be different from the most likely value.
 - Identify which uncertain variables are most important.
 - In the example below, the results are sensitive to the true value of variable Y, but not to the true value of variable X

		Variable X		
		High	Medium	Low
Variable Y	High	+	+	+
	Medium	-	-	-
	Low	-	-	-