American University of Armenia
IE 340 – Engineering Economics
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Ch6 - Public Sector: Benefit/Cost Ratio Analysis

Outline

- Government and Public projects
- Public Goods/Consumer and Producer Surplus
- The concept of Benefit/Cost (B/C) ratio
  - We want Benefits to be higher than costs
- Examples
- Incremental B/C ratio
- Compare with IRR method

Government and Public Projects

- **Public projects** are those funded, owned and operated by a government

- Governmental agencies may have a hand in a number of projects through the provision of loans or other means of financial help, but they are not considered to be public projects

- Most public projects relate to work a government does to fulfill a public purpose, and commonly they include such things as road repair and construction, public building construction, schools, and even public parks.

Public Goods

- A **public good** is a good that is both **non-excludable and non-rival** in that individuals cannot be effectively excluded from use and where use by one individual does not reduce availability to others.

- Examples of public goods include knowledge, lighthouses, national defense, flood control systems or street lighting

Public Goods

- Many public goods may at times be subject to excessive use resulting in negative externalities (air pollution)

- Public goods problems are often closely related to the "free-rider" problem, in which people not paying for the good may continue to access it

Welfare Aim of the Government

- The chief aim of the government is:
  - National defense
  - General welfare of its citizens
- Ultimate goal of the government is to serve its citizens
- Thus, with some exceptions what is good for the citizens has to be good for the government
- BUT, these exceptions are quite important!

Public Activities

- Not all public activities have to have direct impact on ALL the citizens of the country
- Examples:
  - Building a better road between Hrazdan and Tsaghkadzor doesn’t benefit those who never take it
  - Building a new school in Vanadzor doesn’t benefit someone who lives in Goris, or even someone living in Vanadzor, but has no children

Public Activities

- Moreover, some public activities might have a negative effect on a part of the country's population
- Examples:
    - Building a dam on a river might have a positive effect overall (additional source of electrical power for the country), but might harm the inhabitants of a nearby village through environmental changes

Public Activities

- Public projects are usually much more complicated than private projects in many respects

- That is why we dedicate a separate lecture on studying the differences between the two types of activities, and the ways to measure their overall effects

Public vs Private Projects

- There are number of special factors that are not ordinarily found in privately financed projects

- As such the different decision criteria are often used for public projects (Benefit/Cost method)

Main differences between public and private projects

- Purpose:
  - Private projects are more profit oriented, while public projects might stress more on health, protection, etc., even without bringing profit
- Sources of capital:
  - Apart from private funds, public projects can be financed with the receipts of taxes, loans without or at low interest
- Multiple purposes:
  - Public projects are more likely to be multipurpose (e.g. reservoir can serve to generate power, but also for irrigation or for recreation)

Main differences between public and private projects

- **Project Life:**
  - Private projects are usually much shorter (5 to 20 years) than public projects (20 to 60 years)
- **Nature of benefits:**
  - Usually monetary for private projects, often non-monetary for the public ones (difficult to quantify)
- **Conflicting purposes:**
  - Are quite common for the public projects (dam on the river example)

Main differences between public and private projects

- **Beneficiaries of the project**:
  - Normally the private investor himself benefits from his project, but the beneficiaries of projects financed by the government are likely to be the general public
- **Influence of political factors:**
  - Rather rare for private, but quite common for public projects
- **Measurement of efficiency:**
  - Rate of return for private projects. Very difficult to measure for public projects

How to judge on public projects?

Governments do not usually deal with **Profit**, therefore we deal with a different "vocabulary"

- **Benefits** are positive public outcomes (favourable consequences of the project to the public)
- **Disbenefits** are negative public outcomes (negative consequences)
- **Costs** are the monetary disbursements of the government (taxpayers)

How to judge on public projects?

- Benefit/cost ratios are frequently used for government decisions
- Costs accrue to government, but:
  - Benefits frequently accrue to others!
  - Benefits may take on non-monetary forms
  - Some benefits may not be counted!
    - E.g., profits by hospitals due to pollution
  - For some programs, costs exceed benefits!

Judging proposed investments

- For now, we will avoid some of these problems
- In particular, we will assume that:
  - All relevant costs and benefits have been put in dollar terms

- *Any method for evaluating projects in the public sector must consider the worthiness of allocating resources to achieve social goals*

The Benefit/Cost Method

- The Benefit/Cost Method involves the calculation of a ratio of benefits to costs (discounted)

- The B/C ratio is defined as the ratio of the equivalent worth of benefits to the equivalent worth of costs (PW, AW or FW)

- The B/C ratio is also known as the saving-investment ratio (SIR) by the governmental agencies

A project is desirable if…

- $\frac{\text{Benefit}}{\text{Cost}} > 1$
- $\frac{\text{PW of Benefit}}{\text{PW of Cost}} > 1$
- $\frac{\text{AW of Benefit}}{\text{AW of Cost}} > 1$

This means that a project is desirable if Benefits > Cost, making the ratio > 1

This is equivalent to having ∑PW >= 0 and ∑ AW >= 0.

A project is desirable if…

- $$BC = \frac{\text{benefits to the public}}{\text{costs to the government}} > 1$$

  - Benefits: all the advantages less disadvantages to the public
  - Costs: all the disbursements less any savings by the sponsor

Evaluating Independent Projects

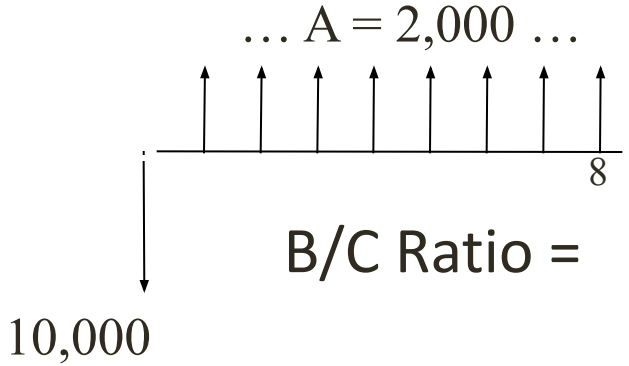
- Independent projects
  - the choice of selecting any project is *independent* of choices regarding any and all other projects
    - None of the projects, any combination of them, all of them

- Whether one project is *better* than another is unimportant
- Criterion for selection: $B/C \geq 1$

Example 1: single project

- You have a project, which requires a first investment of $10,000. The project will increase benefits by $4,000 per year but it will also increase operating costs by $2,000 per year. The lifetime of the project is 8 years.
- Using B/C ratio, and assuming an interest rate of 7%, is this project desirable?

Example 1: single project (cont.)



Interest: 7%

1st Cost: $10,000

Benefit: $2,000/yr.

$$\text{B/C Ratio} = \frac{\text{PW of Benefit}}{\text{PW of Cost}}$$

$$= \frac{2000\,(P/A,\,7\%,8)}{10{,}000}$$

$$= \frac{11{,}940}{10{,}000}$$

= 1.194 > 1, which is good…

Example 2: single project

- You are considering to install or not a new machine. The first cost is $50,000 and it would reduce costs by $3000 per year. In addition, the new machine would require maintenance cost of $700 per year (the old machine required maintenance costs of $200 per year). Assume interest rate = 5%, lifetime = 10 years and SV=0.
- Do a Benefit/Cost analysis and decide if you should buy or not the new machine.

Example 2: single project

- Data:
  - First Cost: $50,000
  - Reduction in operating costs = $3000 per year
  - Change in maintenance cost = (proposed – current) = 700 – 200 = 500 per year
  - Benefits ????

Example 2: single project

- Do B/C ratio calculation
  - Remember to put all the numbers in the same form: PV, AV, or FV
- In this case we will consider:
  - $50,000 as a cost
  - $3000 as a benefit
  - $500 as a reduction in benefits

Example 2: single project

- Benefit/Cost ratio = $\frac{2{,}500\ (P/A, 5\%, 10)}{50{,}000}$
- Benefit/Cost ratio = $\frac{19{,}304}{50{,}000}$
- Benefit/Cost ratio = 0.386

- Decision: Benefit/Cost ratio is less than 1 and therefore not desirable. Do not buy the new machine

Note

- Does my answer change depending if I classify the data as a cost instead of as a reduction in benefits (or classify the data as a benefit instead of a reduction in costs) and vice versa?
  - Yes and No…
- Adding/subtracting a constant amount to the numerator and denominator:
  - Cannot change whether ratio is > 1 or < 1
    - $a+x/b < 1$ vs $a/b-x < 1$
  - But *can* change which ratio is bigger!

In other words…

- Adding/subtracting a constant amount to the numerator and denominator will change your answer, but it will not change the fact that the answer is greater than one or lower than one. Therefore, although your B/C ratio will change, your decision (based on if the B/C ratio is greater or lower than one) will not change.
- **Conventional vs Modified** B/C ratio

For example…

- If we use the previous example, but this time consider:
  - $50,000 as a cost
  - $3000 as a benefit
  - $500 as a cost

- Then, Benefit/Cost ratio = $\frac{3{,}000\ (P/A, 5\%, 10)}{50{,}000+500\ (P/A, 5\%, 10)}$ = **0.43**
- Notice that the answer changed (**0.43 versus 0.386**), but the fact that the number was still less than 1 didn't. Therefore, our decision doesn't change.

Conventional B/C Ratio

- **Benefit/Cost ratio** $= \dfrac{\text{PW(benefits)}}{\text{PW(total costs)}} = \dfrac{\text{PW(B)}}{\text{I + PW(O\&M)}}$

O&M - operating and maintenance costs

I – initial investment

Benefit/Cost ratio $= \dfrac{\text{PW(B)}}{\text{I + PW(O\&M)-PW(SV)}}$

Modified B/C Ratio

- $$\textbf{Benefit/Cost ratio} = \frac{PW(B) - PW(O\&M)}{I}$$

O&M - operating and maintenance costs

I – initial investment

$$\textbf{Benefit/Cost ratio} = \frac{PW(B) - PW(O\&M)}{I - PW(SV)}$$

Comparing Mutually Exclusive Projects

- Mutually exclusive projects
  - At most one project may be selected from a group of projects
- Requires an *incremental* B-C analysis

  ($\Delta B / \Delta C$). WHY? See Example 6-5, p.256

Incremental Analysis

- You need to follow the same principles you used in Incremental IRR…

  1. Decide if each alternative is good by itself
  2. Compare alternatives using incremental analysis

Incremental Analysis

- **Rank the alternatives** in order of increasing total equivalent worth of costs

- The **"do nothing**" is selected as a baseline alternative and compare with the next least cost alternative (alt1)

- **Compute B/C ratio**: is it greater or less than 1?
- If greater than 1 drop do nothing alternative and select alt 1 as the next best alternative

- **Calculate incremental B/C** for the difference in benefits and costs of alt1 and next least cost alternative

Note: NEVER COMPARE ABSOLUTE B/C RATIOS. APPLY INCREMENTAL B/C RATIOS!!!

Example: multiple projects

- You are deciding between three alternatives and you need to pick the best one. The lifetimes of all machines is 20 years. Assuming a 5% interest rate, which machine should you select?
- Use B/C ratio to make your decision

Alternative A

- First cost = $45,000
- Tax benefits = $7,000 per year
- Salvage value of $30,000
- Operating costs = $1,500 per year
- Maintenance costs = $2,000 per year

Alternative B

- First cost = $25,000
- Tax benefits = $3,000 per year
- Salvage value = $15,000
- Operating costs = $2,500 per year
- Maintenance costs = $3,000 per year

Alternative C

- First cost = $65,000
- Tax benefits = $8,000 per year
- Salvage value = $25,000
- Operating costs = $1000 per year
- Maintenance costs = $1500 per year

Summary

	Alternative A	Alternative B	Alternative C
Benefits			
Taxes	$7,000 per year	$3,000 per year	$8,000 per year
Salvage Value	$30,000	$15,000	$25,000
Costs			
First Cost	$45,000 (present)	$25,000 (present)	$65,000 (present)
Operating Expenses	$1,500 per year	$2,500 per year	$1000 per year
Maintenance Costs	$2,000 per year	$3,000 per year	$1500 per year
Lifetime	20 years	20 years	20 years

Incremental Analysis

	Alternative A	Alternative B	Alternative C	(C - A)
Benefits				
Taxes	$7,000	$3,000	$8,000	$1,000
Salvage Value	$30,000	$15,000	$25,000	($5,000)
Costs				
First Cost	$45,000	$25,000	$65,000	$20,000
Operating Expenses	$1,500	$2,500	$1,000	($500)
Maintenance Costs	$2,000	$3,000	$1,500	($500)
Lifetime	20 years	20 years	20 years	
Benefits	$98,542.4000	$43,040.1000	$109,120.1000	$10,577.7000
Costs	$88,617.70	$93,542.10	$96,155.50	$7,537.80
B/C Ratio	1.111994556	0.46011475	1.134829521	1.403287431
Decision	Good, Compare	Not Good, Eliminate	Good, Compare	Good, prefer C

Analysis of Alternative A

B/C ratio for Alt A = $\frac{\text{Benefits}}{\text{Cost}}$

$$= \frac{7{,}000\,(P/A, 5\%, 20) + 30{,}000\,(P/F, 5\%, 20)}{45{,}000 + (1{,}500+2000)\,(P/A, 5\%, 20)}$$

$$= \frac{98{,}542}{88{,}617}$$

= 1.1199 > 1 (Good)

Analysis of Alternative B

B/C ratio for Alt B = $\frac{\text{Benefits}}{\text{Cost}}$

$= \frac{3{,}000\,(P/A, 5\%, 20) + 15{,}000\,(P/F, 5\%, 20)}{25{,}000 + (2{,}500+3000)\,(P/A, 5\%, 20)}$

$= \frac{43{,}040}{93{,}542}$

= 0.4601 < 1 (Bad, Not good)

If we do the same for Alternative C we get a B/C ratio of 1.135, which is > 1 (Good)

Incremental Analysis

	Alternative A	Alternative B	Alternative C	(C - A)
Benefits				
Taxes	$7,000	$3,000	$8,000	$1,000
Salvage Value	$30,000	$15,000	$25,000	($5,000)
Costs				
First Cost	$45,000	$25,000	$65,000	$20,000
Operating Expenses	$1,500	$2,500	$1,000	($500)
Maintenance Costs	$2,000	$3,000	$1,500	($500)
Lifetime	20 years	20 years	20 years	
Benefits	$98,542.4000	$43,040.1000	$109,120.1000	$10,577.7000
Costs	$88,617.70	$93,542.10	$96,155.50	$7,537.80
B/C Ratio	1.111994556	0.46011475	1.134829521	1.403287431
Decision	Good, Compare	Not Good, Eliminate	Good, Compare	Good, prefer C

Incremental Analysis (cont.)

- Note that the benefits and costs are obtained from the previous analysis (we made the analysis in terms of Present Worth)
- For example, for Alternative A:
- Benefits = 7,000 (P/A, 5%, 20) + 30,000 (P/F, 5%, 20)
  = $98,542
- Costs = 45,000 + (1,500+2000) (P/A, 5%, 20)
  = $88,617

Incremental Analysis (cont.)

- Compute Incremental B/C for C-A
- In this case, since Incremental B/C of (C-A) = 1.40 we prefer Alternative C over Alternative A. Since we have no more alternatives we decide that Alternative C is the best one

- Examples 6.6 and 6.7, page 258

Review

- We learned how to compare projects by
  - Net benefit
  - Benefit/cost ratio:
    - Compare projects *against each other* in order of increasing cost
    - Size of ratio does *not* say which is *best!*
- Benefit/cost ratio tells you:
  - Whether an investment is beneficial or not (depending if the B/C ratio is >1 (beneficial) or <1 (not beneficial)