

McPeak
Lecture 14
PPA 723

Costs and Benefits.

A cost is anything that reduces an objective and a benefit is anything that contributes to an objective.

For society as a whole, increasing national income is the objective. Anything that reduces national income is a cost and anything that increases it is a benefit.

Anything that reallocates it from one party to another is a transfer.

Compare to financial analysis where a dollar is a dollar. There, we would worry about tax taking money from us to give to them. Here it is not an issue.

[return to DWL argument and can use example of user fees in the commons]

Transfers:

Tax payment.

Subsidy.

Credit payments.

These don't create or diminish national income, they just move it from one party to another. What is done with the money (loan money to buy fertilizer, fertilizer is a cost increased output is a benefit) impacts national income, but the loan payment does not.

Real resource flows are critical to identify. A tax is a claim on a real resource flow. We are looking to identify uses of the resources.

Steps to Cost-Benefit analysis.

- 1) Define the situation
- 2) Identify and value the costs
- 3) Identify and value the benefits
- 4) Discount future cost and benefits to identify net present value
- 5) Consider the implications of the choice made on NPV income terms for other objectives (equity for example)
- 6) Sensitivity analysis.
- 7) Interpret results

1) Defining the situation:

What is the community whose resources are relevant to the program being evaluated?

What is the spatial extent of the proposed project?

What are the current resources in this community in terms of: money, property, labor, environmental amenities, and government services for the community?

What will happen if the project is not implemented? Identify and value the costs and benefits that arise with the project and compare to the situation without the project.

This is not the same as “before” and “after”.

Incremental net benefit with and without project.

Patterns:

With grows at a faster rate than without.

With stops a decline that will happen without.

With leads to an increase, without a decrease.

2) Identify and value the costs

Physical goods. Materials that are easy to identify.

Labor. People working and getting paid for it.

Land. The place where the project is taking place.

Contingency allowances. Recognizing that there will be changes in physical conditions or prices over the course of the project and putting that in.

Intangibles. Traffic delays, noise... Externalities.

[omit taxes, debt service, sunk costs]

To value these, we return to the concept of economic cost.

Here we expand it some since we have now considered externalities.

The shadow price of an input reflects its value to society as a whole; the full social accounting of the marginal cost of using the input.

If there are market imperfections, it is not the same as the market price.

If the market is perfectly competitive and there are no externalities, then it is the same as the market price (the next best alternative as reflected in the market definition).

3) Identify and value the benefits

New production or increased production from current level.

Quality improvement.

Ability to access higher return markets.

Cost reduction.

Avoided losses.

These (again in the absence of externalities) can be valued through market prices.

Some benefits are difficult to reflect in market prices (civic pride, reduction in pollution,...). To approximate these, we use a variety of techniques to estimate the community's willingness to pay.

4) Discount future cost and benefits to identify net present value

Many projects have benefits and costs that will be realized over time.

How do we compare these values, and arrive at a single measure of the flow of costs and benefits over time?

We compute a single measure of these flows as the present value. We discount future benefits and future costs to arrive at a single statement of the net present value of benefits minus costs.

Why do we discount?

Impatience. Having it now is more valuable than in the future. Longer time to be with the benefit, and also “conditional continuation probability” factors in here.

Inflation. Dollar today is not the same as a dollar in the future.

Opportunity cost. I could have invested the money and earned returns, so this is the economic standard by which I should evaluate future returns.

General form for discounting:

r is the discount rate, usually expressed in annual terms.

Define future value by FV , and present value by PV .

t is a time index, and in our case is indexed in years.

$$FV_t = PV_0 \cdot (1 + r)^t \text{ or } \frac{FV_t}{(1 + r)^t} = PV_0$$

If I promise to pay you \$100 20 years from now, and the discount rate is 6%, what is the present value? In other words, what amount could you give me now, I invest in a sure bet 6% rate of return bond, and have it pay off \$100 in 20 years?

$$\$100/(1+.06)^{20}=\$31.18$$

If it is current year, $\$100/(1+.06)^0 = 100$, since anything raised to the zero power =1 by convention.

If it is a stream of payments, we sum them over time.

$$PV_t = X_t + \frac{X_{t+1}}{(1+r)^1} + \frac{X_{t+2}}{(1+r)^2} + \frac{X_{t+3}}{(1+r)^3} + \dots + \frac{X_{t+s}}{(1+r)^s}$$

[For future reference: if payments are equal over time, and it is over an infinite time horizon, we can use the following result.

$$S = \sum_{k=1}^m a^k = \frac{a^1 - a^{m+1}}{1 - a}$$

$$\sum_{s=1}^{\infty} \frac{1}{(1+r)^s} = \frac{\frac{1}{(1+r)^1} - \frac{1}{(1+r)^{\infty}}}{1 - \frac{1}{(1+r)}} = \frac{\left(\frac{1}{1+r}\right)^{-0}}{\left(\frac{1+r-1}{1+r}\right)} = \frac{1}{r}$$

Distinction between the nominal rate of interest and the real rate of interest.

The nominal rate includes inflation.

The real rate is in terms of inflation adjusted units.

Let gamma be the inflation rate, and i is the real rate of interest.

The nominal rate of return can be stated $1 + \tilde{i} = (1+i)(1+\gamma) = 1+i+\gamma+i\gamma$.

That means the real rate of interest is nominal rate of interest – inflation divided by 1+ rate of inflation. Roughly speaking, we can use nominal rate minus inflation rate to get real rate if inflation is “small”.

Real present value discounts for both real interest rates and inflation.

If your future monetary values are stated in real terms, you do not discount for inflation. They have already been discounted.

If your future monetary values are stated in nominal terms, you need to discount for both inflation and real rate of interest.

Is the contract you signed for a \$100 bill to be handed to you each year, or for the equivalent of \$100 in today's money to be handed to you each year?

The discount rate you choose depends on whether the values you are using for costs and benefits are in real or nominal terms.

Inflation rate is 5%. Nominal rate of interest is 8%.

$(1+.08) = (1+.05)(1+i)$, real interest rate is 2.9%.

Is promise to pay \$100 bill next year? Then $100/(1.08)$, worth \$92.59 today.

Is promise to pay the equivalent of \$100 next year? Then $100/1.029$, worth \$97.18 today.

How do we choose r ? A different r may change the relative evaluation.

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.
 - Example: suppose I will give you \$100 today *or* $\$100(1+r)$ next year.

Today	R	Next year
\$100	0%	\$100
\$100	2%	\$102
\$100	5%	\$105
\$100	10%	\$110

- The point at which you become indifferent between the two choices is your *discount rate*.

Why the discount rate matters

- Discounting affects the value placed on future benefits and costs.
 - Higher discount rates place less importance on future benefits / costs. A lower discount rate increases future values in terms of current values.

Recall:

$$\frac{FV_t}{(1+r)^t} = PV_0$$

- Consider a program with 20 years of benefits at \$1/year.
 - PV = \$20 with 0% discount rate
 - PV = \$15.9 with 3% discount rate
 - PV = \$13.5 with 5% discount rate
 - PV = \$11.6 with 7% discount rate
 - PV = \$9.5 with 10% discount rate

What about using market interest rates?

Economists sometimes use the rate of return at the U.S. Treasury.

- Investors looking for a safe return invest in government securities.

DATE	3-mo	6-mo	1-yr	2-yr	3-yr	5-yr	7-yr	10-yr	20-yr	30-yr
11/01/1990	7.28	7.38	7.32	7.68	7.88	8.15	8.42	8.57	8.63	8.70
11/01/1995	5.48	5.49	5.46	5.52	5.62	5.74	5.86	5.98	6.36	6.29
11/01/1999	5.16	5.32	5.47	5.83	5.93	6.00	6.23	6.06	6.55	6.19
11/01/2002	1.44	1.43	1.42	1.46	1.76	2.14	2.92	3.54	4.01	5.07

A problem occurs if, when comparing two options, one is riskier. Using a risk-free rate favors the riskier project.

Another alternative is to consider where the funds for a project come from.

If some of the funds come from the private sector, we should consider the opportunity cost of using those funds. This is a good estimate of the opportunity cost of the capital you are using. Rate of return on capital is around 10%, so we use 10%.

The Office of Management and Budget directs agencies to use a 7% real discount rate. This rate approximates the marginal pre-tax rate of return in the private sector.

Might the social discount rate deviate from these market rates?

Social discount rate – the interest rate at which society is willing to trade future consumption for present consumption.

Some economists argue that the opportunity cost of foregone future consumption might differ from the opportunity cost revealed in the markets.

Reasons social discount rates may differ from market rates

- 1) Concern for future generations
 - Private sector may save too little, because it doesn't care about future generations.
 - Thus, the government acts as an advocate for future generations, who are not represented in the marketplace.

Estimate by Costanza et al. (1997) of the value of the annual flow of goods and services from the environment. 33 trillion.

Years	5% discount	10% discount
1	31390571008524	29859634795187
10	20015511770517	12140021558658
100	222352250970	1498197682
200	1498197682	68018
300	10094777	3
400	68018	0
500	458	0
600	0	0

Discounting can lead to outcomes that are “pretty grim” for future generations.

- 2) Market inefficiency
 - Investments create knowledge, a positive externality (spillovers / leaks).
 - Thus, one can argue that firms under-invest.

Sometimes you see a 10% rate by convention.

Example: Compare costs of paving a road and gravelling a road.
Present Value Cost computation.

Gravelling costs \$28,000 to do now, and requires \$2,000 per year upkeep for the next 10 years.

Paving costs \$35,000 to do now, and requires \$1,000 per year upkeep over the next 10 years.

Discount rate is 10%. Say this is the nominal rate of return on capital, and these values are nominal values (signing a contract).

	Gravel	Pave
Now (t=0)	28,000	35,000
1	$2,000/(1+.1)^1=1,818$	$1,000/(1+.1)^1= 909$
2	$2,000/(1+.1)^2=1,653$	$1,000/(1+.1)^2= 826$
3	$2,000/(1+.1)^3=1,503$	$1,000/(1+.1)^3= 751$
4	$2,000/(1+.1)^4=1,366$	$1,000/(1+.1)^4= 683$
5	$2,000/(1+.1)^5=1,242$	$1,000/(1+.1)^5= 621$
6	$2,000/(1+.1)^6=1,129$	$1,000/(1+.1)^6= 564$
7	$2,000/(1+.1)^7=1,026$	$1,000/(1+.1)^7= 513$
8	$2,000/(1+.1)^8= 933$	$1,000/(1+.1)^8= 467$
9	$2,000/(1+.1)^9= 848$	$1,000/(1+.1)^9= 424$
10	$2,000/(1+.1)^{10}= 771$	$1,000/(1+.1)^{10}= 386$

GRAVEL: \$40,289

PAVING: \$41,144

Gravel is less costly than paving in PV terms.

If we add in benefits, we can arrive at net present value.

Assume the impacted population is of size 1000. Also assume we did a study that indicates that the average monetary value per year the population of 1000 of an improved road is \$8 if paved and \$6 if gravel (each). So the total annual benefits of the gravel road are \$6000 and total annual benefits of the paved road are \$8000.

$$NPV_{\text{paving}} = 8,000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t} - 35,000 - 1,000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t}$$

$$NPV_{\text{gravel}} = 6,000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t} - 28,000 - 2,000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t}$$

If the discount rate = 6%, then $NPV_{\text{paving}} = \$16,520$, while $NPV_{\text{gravel}} = \$1,440$.

If the discount rate = 10%, then $NPV_{\text{paving}} = \$8,012$, while $NPV_{\text{gravel}} = -\$3,422$.

Note that as the discount rate increases, future (net) benefits have less weight against the current period costs. Choice of discount rate can influence which project is selected in Cost Benefit analysis (though not in this case).

Another measure is sometimes used; the internal rate of return. What r leads to PV benefits equal to PV costs?

For the paving project, just over 15% makes $NPV=0$. For the gravel project, it is a bit over 7%.

Solve for the r that makes:

$$7,000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t} = 35,000$$

$$4,000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t} = 28,000$$

Also note we can consider the benefit cost ratio, under the rule that if it is greater than one, the benefits outweigh the costs.

$$B - C \text{ ratio}_{\text{paving}} = \frac{8,000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t}}{35,000 + 1,000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t}}$$

The ratio is 1.40 at a discount rate of 6% for the paving project.

5) Consider other factors that weigh in the decision: Equity, impact on sub-groups, things like this.

While the average benefit is indeed \$6 or \$8 for our community members, this is highly skewed, as only 500 people have vehicles. The other members will not have any direct benefit from road improvement, but will have to pay the costs.

The gravel road will not be strong enough for the family farm to drive their tractor on so they will not benefit from this, but will benefit from the paving.

6) Sensitivity of results.

As you have seen by now, the assumptions can lead to changed assessment.

With regard to the discount rate, it is sometimes useful to identify where is the “crossing point”.

If we keep the original values, it is never going to make more sense to gravel than pave given these values.

If we change our original problem and make the cost of gravelling cheaper (say it is 18,000 rather than 28,000) we choose paving when r is less than 12% and gravel when r is greater than 12%.

Also, the values we came up with for our benefits could be off. Say the costs were as reported in the original problem, but the benefits of the gravel and paved road were overstated by half (like in the windmill example).

NPV for the gravel road is $-\$20,640$, while for the paved road it is $-\$12,920$.

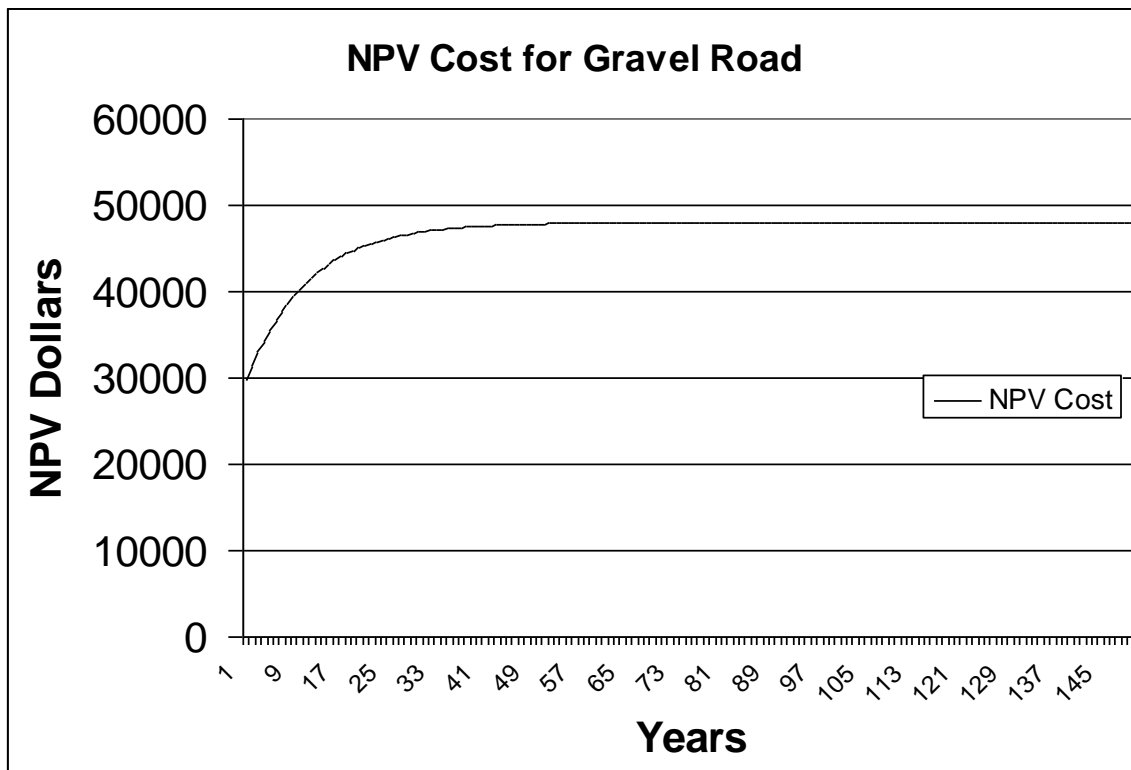
Neither project makes sense at a discount rate of 10% - alternative uses of the resources offer better options.

One other source of uncertainty (as if ambiguity about the discount rate, the way we can make the prediction change by changing the benefit estimation is not enough) is the length of

the time horizon. Are we really sure the time horizon is 10 years?

If for example we use the 6% rate and have a horizon of 2 years, it is better to gravel than pave (recall we picked pave). If it is anything more than 10 years, we have understated the NPV (for example, the paved road NPV if it lasts 20 years is 2.7 times as large as the NPV if it lasts 10 years).

Longer time horizons tend to flatten out future costs and benefits as suggested by the Costanza et al. result above.



7) Interpreting results.

Look at NPV, and if you want other perspectives, the internal rate of return and the benefit cost ratio.

Consider how sensitive the results are to your assumptions and how sure you are of your assumptions.

Consider the NPV result as statement of economic efficiency and balance this against other objectives that may be important: equity, targeting specific sub-groups, righting historical wrongs, political stability – whatever.

Realize that as a producer of this information, how important it is for you to act carefully and ethically.

Realize that as a consumer of this information that the careful ethical approach is not always adopted.