

Introduction to Benefit Cost Analysis

HST, IMK, ARF

Introduction

- *Cost-benefit analysis* is a set of practical procedures for guiding public expenditure decisions.

Present Value

- Project evaluation usually requires comparing costs and benefits from different time periods
- Dollars across time periods are not immediately comparable, because of inflation and returns in the market.

Present Value: Currency into the Future

- Suppose you invest \$100 today in the bank
 - At the end of year 1, it is worth $(1 + .05) \times \$100$, or \$105
 - At the end of year 2, it is worth $(1 + .05) \times \$105$, or \$110.25
 - The interest compounds over time, that is the interest is also earning interest

Present Value: Currency into the Future

- Define
 - R = initial investment amount
 - r = rate of return on investment
 - T = years of investment
- The future value (FV) of the investment is:

$$FV = R(1 + r)^T$$

Present Value: Currency into the Future

- Suppose someone promises to pay you \$100 *one year from now*.
- What is the maximum amount you should be willing to pay today for such a promise?
- You are forgoing the interest that you could earn on the money that is being loaned.

Present Value: Currency into the Future

- 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 the money in the future.

Present Value: Currency into the Future

- Define
 - R = amount to be received in future
 - r = rate of return on investment
 - T = years of investment
- The present value (PV) of the investment is:

$$PV = \frac{R}{(1 + r)^T}$$

Present Value: Future Currency into the Present

- In previous equation, r is often referred to as the *discount rate*, and $(1+r)^{-T}$ is the *discount factor*.
- Finally consider a promise to pay a stream of money, $\$R_0$ today, $\$R_1$ one year from now, and so on, for T years?

$$PV = R_0 + \frac{R_1}{(1+r)} + \frac{R_2}{(1+r)^2} + \dots + \frac{R_T}{(1+r)^T}$$

Present Value: Future Currency into the Present

- Present value is an enormously important concept
- A \$1,000,000 payment 20 years from now is only worth today:
 - \$376,889 if $r = .05$
 - \$148,644 if $r = .10$

Present Value: Inflation

- *Nominal amounts* are valued according to the level of prices in the year the return occurs.
- *Real amounts* are valued according to the level of prices in one particular year.
- Inflation affects both the payout stream, and the discount factor, and these two cancel each other out.

Stages in the application process

- Identify all costs and benefits
- Measure them
- Discount them back to common time period
- Assess whether $\text{benefits} > \text{costs}$
- Assess who bears the benefits and costs
- Perform sensitivity analysis
- Assess whether proposal is worth it

CBA of tree clearing

Impacts	Benefits	Costs
Property level		
- direct, medium term	Income from improved pasture production	Cost of clearing trees, improving pasture, controlling regrowth
- indirect, longer term	Possible reduction in grazing pressure on rest of property	Reduced benefit of tree cover (eg shade, shelter, nutrient recycling)
	Improved access for mustering	Pastoralists own value for risk of salinity, erosion
		Pastoralists own value for biodiversity loss
External impacts		
- Social value of land quality	Possible reduction in land degradation on some properties	Possible increased risk of salinity/erosion above landholder expectations and on other properties
- Cost of greenhouse gases		Impact of land clearing on greenhouse gas emissions
- Social value of biodiversity		Effect of tree clearing on biodiversity
- Indirect effects of production	Social value of positive effects on rural communities	

Identification of impacts

- Major problem in the past is that only financial costs and benefits were identified - many environmental and social ones ignored
- Not always easy to be sure what the outcomes will be of a project
- Not always agreement about what are important social and environmental impacts to include

Private Sector Project Evaluation

- Suppose there are two projects, X and Y
- Each entails certain benefits and costs, denoted as B^X , C^X , B^Y , and C^Y .
- Need to ask:
 - Is the project *admissible*?
 - Is the project *preferable*?

Private Sector Project Evaluation

- Admissible: Are the benefits greater than the costs?
- Preferable: Are the net benefits the highest?
- Most projects involve a stream of benefits and costs over time.

Private Sector Project Evaluation

- Define:

$$B_t^i = \text{Benefits from project } i \text{ at time } t$$

$$C_t^i = \text{Costs from project } i \text{ at time } t$$

Then the present value of project i is:

$$PV^i = (B_0^i - C_0^i) + \frac{(B_1^i - C_1^i)}{(1+r)} + \dots + \frac{(B_T^i - C_T^i)}{(1+r)^T}$$

Private Sector Project Evaluation

- The *present value criteria* for project evaluation are that:
 - A project is admissible only if its present value is positive
 - When two projects are *mutually exclusive*, the preferred project is the one with the highest present value.

Private Sector Project Evaluation

- Table 11.2 shows two different projects (R&D or Advertising).
- The discount rate plays a key role in deciding what project to choose, because the cash inflows occur at different times.
- The lower the discount rate, the more valuable the back-loaded project.

Table of Comp.

Table 11.2 Comparing the present values of two projects

<i>Year</i>	Annual Net Return		<i>r =</i>	PV	
	<i>R&D</i>	<i>Advertising</i>		<i>R&D</i>	<i>Advertising</i>
0	-\$1,000	-\$1,000	0	\$150	\$200
1	600	-0-	.01	128	165
2	-0-	-0-	.03	86	98
3	550	1,200	.05	46	37
			.07	10	-21

Private Sector Project Evaluation

- Several other criteria are often used for project evaluation, but can give misleading answers
 - Internal rate of return
 - Benefit-cost ratio

Private Sector Project Evaluation

- The *internal rate of return*, ρ , is defined as the ρ that solves the equation:

$$0 = (B_0 - C_0) + \frac{(B_1 - C_1)}{(1 + \rho)} + \dots + \frac{(B_T - C_T)}{(1 + \rho)^T}$$

The IRR is the discount rate that would make the present value of the project equal to zero.

- Admissible if $\rho > r$
- The flawed analysis would choose an admissible project with the higher internal rate of return, ignoring scale

Private Sector Project Evaluation

- The *benefit-cost ratio* divides the discounted stream of benefits by the discounted stream of costs. In this case
- B=stream of benefits and C=stream of costs:

$$B = B_0 + \frac{B_1}{(1+r)} + \dots + \frac{B_T}{(1+r)^T}$$

$$C = C_0 + \frac{C_1}{(1+r)} + \dots + \frac{C_T}{(1+r)^T}$$

Private Sector Project Evaluation

- Admissibility using the *benefit-cost ratio* requires:

$$\frac{B}{C} > 1$$

This ratio is virtually useless for comparing across admissible projects however.

Ratio can be manipulated by counting benefits as “negative costs” and vice-versa.

Discount rate for government projects

- Government decision making involves present value calculations
- Costs, benefits and discount rates are somewhat different from private sector

Discount rate for government projects

- Less consensus on appropriate discount rate in public sector. One possibility are *rates based on returns in private sector*.
 - Assumes all of the money that is raised would have been invested in a private sector project
 - In reality, funding comes from a variety of sources – investment and consumption
 - Funding that come from consumption should be discounted at the *after-tax* discount rate
 - Hard in reality to determine what proportions of funding come from consumption or investment

Discount rate for government projects

- Another possibility is the *social rate of discount* – which measures the valuation society place on consumption that is sacrificed in the present.
- Differs from market returns because it:
 - Accounts for *concern about future generations*
 - Involves *paternalism*
 - May solve some *market inefficiency* such as positive externalities

Discount rate for government projects

- In reality, federal agencies are required to use a real rate of return of 7%, on the assumption that this measures the before-tax rate of return in the private sector.
- Some use 2% real return instead, thought to measure the after-tax rate of return.

Discount rate for government projects

- When a new tax or expenditure is introduced, its effects over a 5-year or 10-year period are analyzed to see whether it will put the budget out of balance
 - Ignores discounting
 - Costs (or benefits) outside of the window are not counted toward deficit (or surplus)

Profit today versus profit tomorrow

- ▶ Money today is not the same as money tomorrow
 - need way to *convert* tomorrow's money into today's
 - important since firms make decisions over time
 - is it better to make profit now or invest for future profit?
 - how should investment in durable assets be judged?
 - sacrificing profit today imposes a cost
 - is this cost justified?
- ▶ Techniques from financial markets can be applied
 - the concept of *discounting* and *present value*

The concept of discounting

▶ Take a simple example:

- you have \$1,000
- this can be deposited in the bank at 5% per annum interest
- or it can be loaned to a start-up company for one year
- how much will the start-up have to contract to repay?
- $\$1,000 \times (1 + 5/100) = \$1,000 \times 1.05 = \$1,050$

• More generally:

- you have a sum of money Y
- can generate an interest rate r per annum (in the example $r = 0.05$)
- so it will grow to $Y(1 + r)$ in one year
- but then Y today trades for $Y(1 + r)$ in one year's time

▶ Two special cases can be considered

Case 1: The net revenues in each period are identical

$$Z_1 = Z_2 = Z_3 = \dots = Z_T = Z$$

Then the present value is:

$$PV = \frac{Z}{(1 - R)} (R - R^{T+1})$$

Case 2: These net revenues are constant and perpetual

Then the present value is:

$$PV = Z \frac{R}{(1 - R)} = Z/r$$

Present value and profit maximization

- ▶ Present value is directly relevant to profit maximization
- ▶ For a project to go ahead the rule is
 - the present value of future income must at least cover the present value of the expenses in establishing the project
- ▶ The appropriate concept of profit is profit over the lifetime of the project
- ▶ The application of present value techniques selects the appropriate investment projects that a firm should undertake to maximize its value

Efficiency and Surplus

- Can we reallocate resources to make some individuals better off without making others worse off?
- Need a measure of well-being
 - **consumer surplus**: difference between the maximum amount a consumer is willing to pay for a unit of a good and the amount actually paid for that unit
 - aggregate consumer surplus is the sum over all units consumed and all consumers
 - **producer surplus**: difference between the amount a producer receives from the sale of a unit and the amount that unit costs to produce
 - aggregate producer surplus is the sum over all units produced and all producers
 - **total surplus** = consumer surplus + producer surplus

Efficiency and surplus: illustration

The demand curve measures the willingness to pay for each unit
Consumer surplus is the area between the demand curve and the equilibrium price

The supply curve measures the marginal cost of each unit
Producer surplus is the area between the supply curve and the equilibrium price

Aggregate surplus is the sum of consumer surplus and producer surplus
The competitive equilibrium is efficient

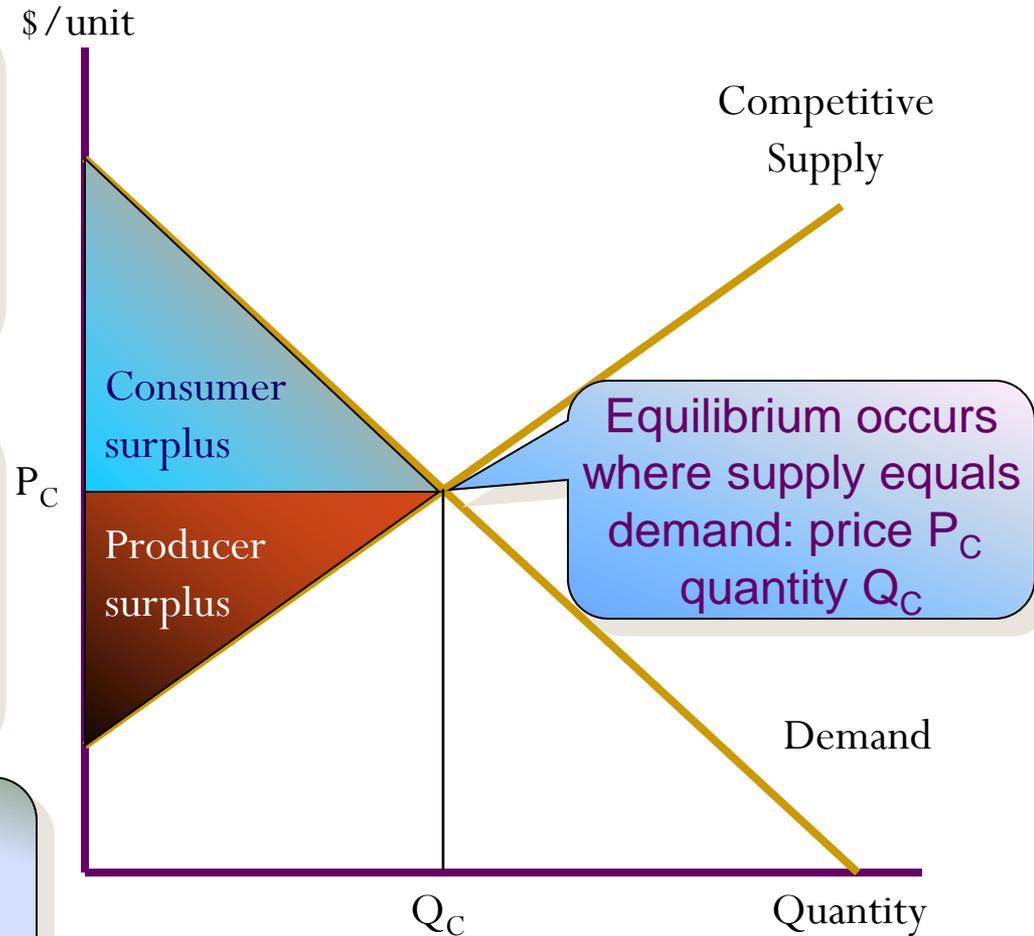
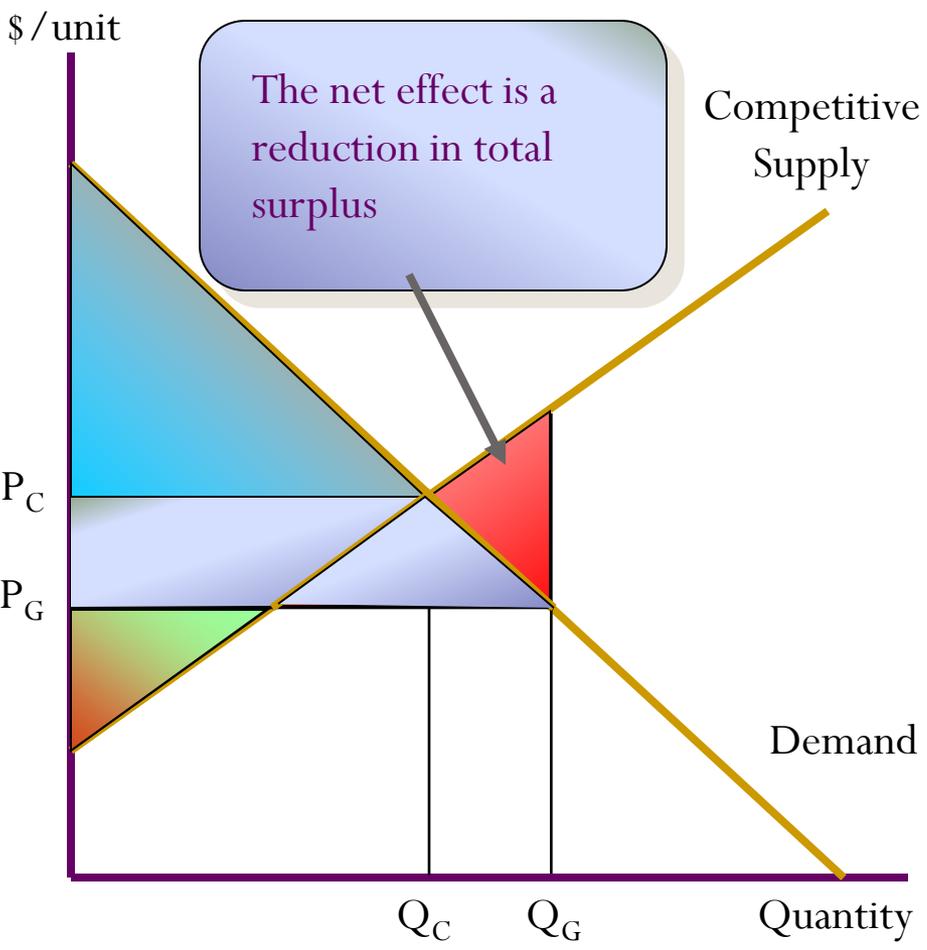


Illustration (cont.)

Assume that a greater quantity Q_G is traded
Price falls to P_G

Producer surplus is now a positive part and a negative part

Consumer surplus increases
Part of this is a transfer from producers
Part offsets the negative producer surplus



A Non-Surplus Approach

- Take a simple example
- Monopolist owns two units of a valuable good
- There are 50,000 potential buyers
- Reservation prices:

Number of Buyers	Reservation Price
First 200	\$50,000
Next 40,000	\$30,000
Last 9,800	\$10,000

Both units will be sold at \$50,000; no deadweight loss

Why not? Monopolist is *small* relative to the market.

Example (cont.)

- Monopolist has 200 units
- Reservation prices:

Number of Buyers	Reservation Price
First 100	\$50,000
Next 40,000	\$15,000
Last 9,900	\$10,000

Now there is a loss of efficiency and so deadweight loss no matter what the monopolist does.

Recall Theory of Cost-Benefit Analysis

Public Policy Objective: Choose the level of output of a good or service to maximize net social benefits (NSB)

$$\text{NSB} = \text{TSB} - \text{TSC}$$

where

TSB = total social benefits

TSC = total social costs

Marginal Social Benefit (MSB) = additional social benefits from one more unit of output

Marginal Social Cost (MSC) = additional social costs of producing one more unit of output

$$\text{MSB} = d \text{ TSB} / d Q$$

$$\text{MSC} = d \text{ TSC} / d Q$$

Q = quantity of a publicly provided good or service

NSB are max when $\text{MSB} = \text{MSC}$ ⇨

Social Decision Rule: Choose Q for which $\text{MSB} = \text{MSC}$

Adjusting for the Time Dimension of Environmental Benefits and Costs

- Present Value Determination – a procedure that discounts a future value (FV) into its present value (PV) by accounting for the opportunity cost of money
 - Discount factor – the term $1/(1+r)^t$, where t is the number of periods
 - Social discount rate – discount rate used for public policy initiatives based on the social opportunity cost of funds

Adjusting for the Time Dimension of Environmental Benefits and Costs

- Inflation correction – a magnitude stated in terms of the current period
 - Nominal value – a magnitude stated in terms of the current period
 - Real value – a magnitude adjusted for the effects of inflation
 - Deflating – converts a nominal value into its real value

Adjusting for the Time Dimension of Environmental Benefits and Costs

- Summary of Deriving Time-Adjusted Benefits and Costs
 - Present value of benefits (*PVB*) – the time-adjusted magnitude of incremental benefits associated with an environmental policy change
 - Present value of costs (*PVC*) – the time adjusted magnitude of incremental costs associated with an environmental policy change

The Final Analysis: Comparing Environmental Benefits and Costs

- Step One: Determining Feasibility
 - Benefit-cost ratio – the ratio of PVB to PVC used to determine the feasibility of a policy option if its magnitude exceeds unity
 - Present value of net benefits ($PVNB$) – the differential of ($PVB - PVC$) used to determine the feasibility of a policy option if its magnitude exceeds zero

The Final Analysis: Comparing Environmental Benefits and Costs

- Step Two: Decision Rules to Select Among Feasible Options
 - Maximize the present value of net benefits (*PVNB*) – a decision rule to achieve allocative efficiency by selecting the policy option that yields greatest excess benefits after adjusting for time effects
 - Minimize the present value of costs (*PVC*) – a decision rule to achieve cost–effectiveness by selecting the least-cost policy option that achieves a preestablished objective

Reservations About the Use of Benefit-Cost Analysis

- Measurement Problems
 - Estimation is particularly problematic due to intangibles
 - Implicit costs
- Equity Issues
 - Distribution of benefits and costs may be highly skewed

Valuing Public Benefits and Costs

- Recall that the discount rate, benefits, and costs are needed to compute the present value of a project
- For private company:
 - Benefits = revenues received
 - Costs = firm's payments for inputs

Valuing Public Benefits and Costs

- For public sector, market prices may not reflect *social* benefits and costs.
 - Externalities, for example
- Several ways of measuring benefits and costs
 - Market prices
 - Adjusted market prices
 - Consumer surplus
 - Inferences from economic behavior
 - Valuing intangibles

Valuing Public Benefits and Costs

- Market prices
 - In a properly functioning competitive economy, the price of a good simultaneously reflects its marginal social cost of production and its marginal value to consumers.
 - Ignores market imperfections
 - Easy to gather

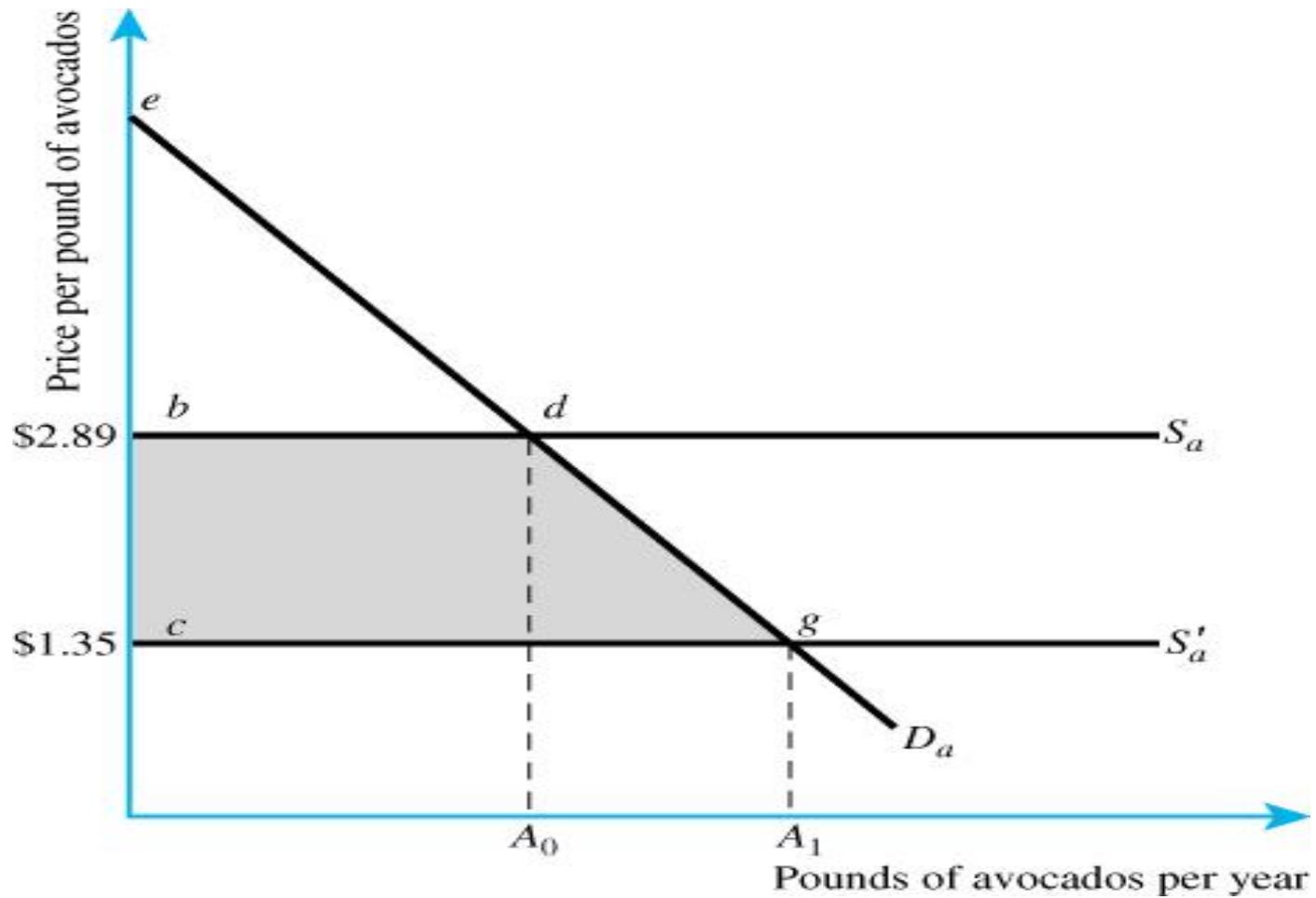
Valuing Public Benefits and Costs

- Adjusted market prices
 - If markets are imperfect, prices generally do not reflect true marginal social cost
 - *Shadow price* of a commodity is its true, underlying marginal social cost, which can sometimes be estimated
 - Examples where insights can be gleaned include monopoly price, taxes, and unemployment

Valuing Public Benefits and Costs

- Consumer surplus
 - Public sector projects can be large, and change market prices
 - Figure 11.1 measures the change in consumer surplus from a government irrigation project that lowers the cost of agricultural production

Figure 11.1



Valuing Public Benefits and Costs

- In this figure, the *change* in consumer surplus is area *bcgd*.
- Provided the government planner can accurately measure the demand curve, the project's benefit can be measured with this change.

Valuing Public Benefits and Costs

- Inferences from Economic Behavior
- Many times a good in question is not explicitly traded, so no market price exists.
- Examples:
 - Value of time
 - Value of life

Valuing Public Benefits and Costs

- Value of time
- In cost-benefit analysis, need to estimate the value of time to take advantage of theory of leisure-income choice.
 - After-tax wage is often used
 - But hours of work not always a “choice,” and not all uses of time away from job equivalent.

Valuing Public Benefits and Costs

- Researchers have examined value of time by travel commuting *choices*.
 - Trains are more expensive, but less time-consuming, than buses. The same is true about non-stop airline flights versus those with a layover.
 - Estimates are that value of time approximately half of the before-tax wage.

Valuing Public Benefits and Costs

- Value of life
- The mindset that “life is priceless” presents obvious difficulties for cost-benefit analysis.
- If the benefits of a saved life are infinite, any project that leads to even a single life saved has an infinitely high present value.

Valuing Public Benefits and Costs

- Economists use two methods to assign finite values to human life:
 - ***Lost earnings***: Net present value of individual's after-tax earnings over lifetime.
 - Taken literally, no loss for aged, infirm, or severely handicapped
 - ***Probability of death***: Most projects affect *probability* of death (e.g. cancer research). People are willing to accept increases in the probability of death for a finite amount of money.

Valuing Public Benefits and Costs

- Examples:
 - Purchasing a more expensive, safer car with a lower probability of death versus a less expensive, less safe car.
 - Occupational choice: Riskier jobs have higher wages, all else equal
 - Willingness to pay for safety devices like smoke alarms.

Valuing Public Benefits and Costs

- Estimates suggest value of a life between \$4,000,000-\$9,000,000
- Can contrast this versus the cost per life saved:
 - Emergency floor lights on airplanes cost about \$900,000 per life saved
 - Asbestos removal rules cost \$100,000,000 per life saved

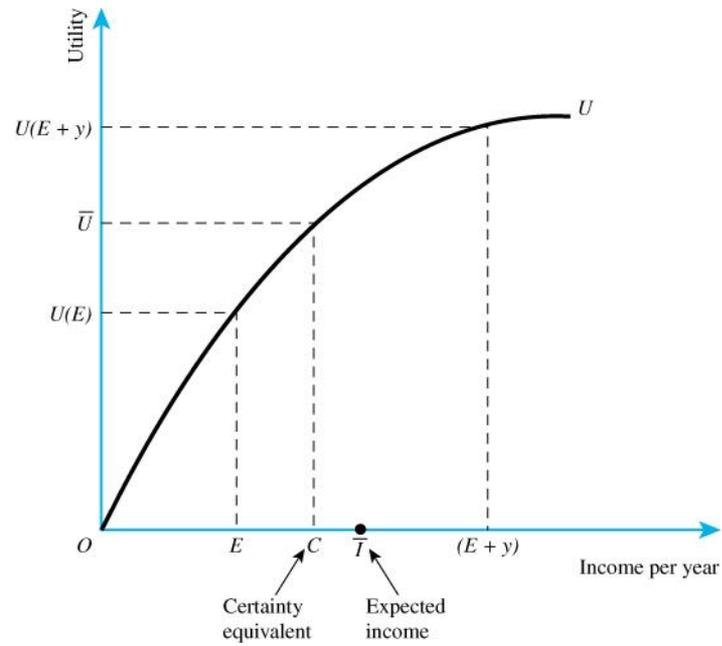
Valuing Public Benefits and Costs

- Valuing intangibles
 - National prestige, others
- Can be used to subvert entire cost-benefit analysis
- Could use difference between costs and benefits to make an argument on how large intangibles would have to be to make the project admissible

Uncertainty

- The results of many projects are *uncertain* (e.g., AIDS vaccine research or defense research).
- In risky projects, benefits or costs must be converted into *certainty equivalents* – the amount of certain income the individual would trade for a set of uncertain outcomes generated by project.
- Requires information on distribution of returns, and risk aversion.

Figure on Uncertainty



Valuing Costs and Benefits

- One of the key stages in Cost-Benefit Analysis was to measure all the costs and benefits
- Normally do this in terms of dollar values
- Not always easy, because some items (eg biodiversity protection) are not traded in markets
- Need special non-market valuation techniques to handle these cases

Non-market valuation techniques

- Revealed preference techniques
 - Travel cost method
 - used for recreation impacts
 - Hedonic pricing
 - used for housing/lifestyle impacts
- Averted expenditure techniques
 - Often used to estimate the value of indirect use benefits
 - Storm protection benefits of mangroves

Non-market valuation techniques 2

- Stated preference techniques
 - Contingent valuation
 - Choice modelling
- These are capable of estimating non-use values
- Key techniques to use in relation to values for biodiversity
- But often complex, expensive and time consuming to apply